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THE RIDDLE OF THE EARTH: EFFORTS TO READ IT.

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We are creatures living upon an object which astronomers tell us is only one of myriads of millions of globes, stars, flaming suns and whirling masses spread out into an immensity of space whose limits are far beyond our knowing.

We are prisoners upon a ship sailing the oceans of the universe. Whether there are other worlds, other celestial ships, like our own, whose passengers like ourselves are peering out into the mysteries of space and unmeasured time, trying to read the meaning of it all, we must leave now to speculation and to the dreamers, mystics, and scientists of the remote future.

When we walk the decks of our celestial bark, and when we try to discover what cargoes lie within its deeper holds; when we try to comprehend the power of its engines, we are once more confronted with the vastness of nature and with our individual nothingness.

This earth is a machine; it is a storehouse of energies, of powers, and from time to time we are made all too painfully aware of its stupendous vitality, its reserves of devastating force. Yet to this force we must in some ways adjust ourselves, for over its energy we have no ultimate control. The

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earth is a riddle; one of the most urgent of all riddles in its demands upon us; for upon this earth we are born, from it we live, and by the teachings of every great religion known to history we carry in our bodies the dust of the ground. Yet bound as we are by physical limits, the soul of man, his sense of reason and his immortal spirit compel him to ask again and again, what is this earth? How is it constructed? Will it hold together for the expected duration of all human life, or will it in obedience to ancient prophecies and the predictions of modern alarmists hurl all things into the eternal mysteries of creation, death and possible rebirth?

Yet as the earth has its mysteries so too has the mind of man; for when we ask how we may attempt to solve the mystery of our earth we shall be met by as strange a medley of facts, ideas, fancies, science and speculations as perhaps ever confronts the student of human thought. But there are reasons for all this. It is not easy

> "To see a world in a grain of sand,
> And a Heaven in a wild flower,
> Hold Infinity in the palm of your hand,
> And Eternity in an hour."

And yet it is by the study of such things as grains of sand; the flowers of the life of the great ages behind us, and by our striving to understand at least some of the meanings of forces which seem eternal and universal that we have come to some conceptions of what the earth is all about.

Practical facts, ideas of good and evil, theological doctrines, geological dogmas, observation and experiment have all had their place in the efforts to read the riddle of the earth. What I propose to do in this discussion is in the main two things.

First arrange into historical sequences the story of some of the major experiences and ideas of members of the human family in their actual contacts with the earth. Secondly to try to show how out of these long continued, and often apparently useless efforts there has gradually come into being a science of the earth. A science in which the earth shall be considered, as far as the human mind may do so, as having energies of its own, a behavior of its own, and lastly an historic growth and development.

Should there be any who choose to believe both the effort and the result are useless, or at best altogether inadequate, I can do no better than to quote the words of John Playfair,[1] one of the founders and advance guard of the geological science in the eighteenth century.

> "in science, presumption is less hurtful than despair, and inactivity is more dangerous than error."

But I wish primarily to set forth a background, and establish a perspective. A complete account of geological science is not a theme for an hour.

It is generally agreed among scholars that the sense of the practical necessities of life appeared in human society before the construction of any science, or serious philosophy. "Since man first acquired the ability to examine the conditions of his existence, his first occupation has always been the safeguarding of his own life."[2]

We arrange then the contacts of man with the earth into distinct historic stages, although it must be granted that these are dependent upon each other, and often overlap. In fact all of them may be said to survive in some shape in most of human society.

The first stage then I have called "Earth Behaviorism," since man first of all, and rather painfully, was forced to adjust his own behavior to the nature of the materials around him.

We are very apt in these sophisticated modern days to affect an air of superiority to our far remote ancestors, and say that science was easier then than now because everything was as yet undiscovered. But there is more than a reasonable doubt as to this, as a short inspection of some actual earth materials will prove. Early man acquired a rock technique.

But this technique acquired slowly was two fold:
First of all individual by isolated efforts.
Second social, through war, pillage, self-defense and conquest.
By the discovery that then as now there were especially gifted individuals who acquired a reputation.

We may imagine the growth a distinct cult; a Stone Ax Union.

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[1] "Illustrations to the Huttonian Theory," p. 511. Edinburgh, 1802.

[2] Prof. Elliott Smith, "Human History."

But out of this came the truth that the things of the earth are possessed of those qualities we today call by the name of *Physical Constants:* manner of breaking; shaping, hardness; colors. Thus in spite of himself man became a behaviorist; only the behavior was first of all earth behavior, not his own.

By this study of rock and earth behavior man advanced in technique, so we have so-called ages of material culture: The Ages of Stone, Bronze, Iron; to which we may truthfully add with no loss of perspective, The Age of Concrete.

But all this is an advance of experience, of skill in materials, rather than the construction of science. It is knowledge of concrete objects.

MAN AND NATURAL ENERGY. THE POWER OF THE UNSEEN.

But by this time man has lived long enough, has experienced enough to see that beyond these material objects with which he deals are other parts of nature over which he has no control, about which he has no certain knowledge, and some of which may do him actual injury.

He has accomplished a great deal, has much experience, but he is overcome by the power of forces which he feels, but cannot see. His muscularity is now fairly pitted against things wherein muscle is of less use than understanding, for he is starting upon his long quest to fathom by human intelligence the reality and meaning of the powers of nature.

He must have an explanation: he demands something in these powers of nature by which he may take hold of them, if needs be try to modify them; at the last adjust himself to them.

Natural religion, deification of the forces of nature, came logically enough in the gods of fire, and in the countless divinities of all primitive peoples. Hence conceptions of good and evil associated with natural force. Are we, are you satisfied that volcanoes are not evil?

RISE OF COSMIC THEORIES.

Eventually all of these apprehensions and experiences were formulated into a systematic effort to coördinate nature in all of the various phases. In Asia, in the lands of the old Mediterranean world; in Greece, and in the gardens and rivers of China and India, there sprang into being an attitude towards man and his earth which turned men from being merely hunters, axemakers and killers into philosophers, poets, artists, religionists and expounders of the ultimate meanings of things of earth and sky.

Buddha. "The ideal of the Buddhist faith consists in realizing, through spiritual experience and in moral acts, the continuity of life in man and nature and the fellowship of all beings."[3] To modern Western thought Buddhism seems to signify the conception of the earth as only one phase of an existence which in its entirety must contain all the universe of materials and ideas. In which the human individual dies, but is comprehended in the life of all things, of birds, and all animals; all plants. If a non-expert suggestion may be ventured, Buddhism comes into contact with certain phases of modern physical science in its efforts to solve the problem of the universal. To that extent at least Buddha must be placed among those who have attempted the solution of man and the cosmos: the place of earth.

The Rise of the Hebrew Scriptures. To these sources we owe the definite introduction into the writings of the world of Creative Energy comprised in One Supreme Being. Not an endless series of rebirths, recreations, but, and the point is significant, the conception of the making of the earth as a definite series of stages, of steps and processes. It certainly cannot be necessary to elaborate the point, since modern geological science is based upon the ideas of an evolution of earth form and substance. It contains obviously the conception of self-conscious design in earth and nature.

In these efforts to find some adjustments of man and nature the names and ideas of certain ones have come down to us with an insight and a power of interpretation which have long since fixed them permanently in the pages of history. To them we owe, in their attempts to identify natural things with earth and life, the first definitely written out cosmic theories. Because of their influence we may then ascribe to them,

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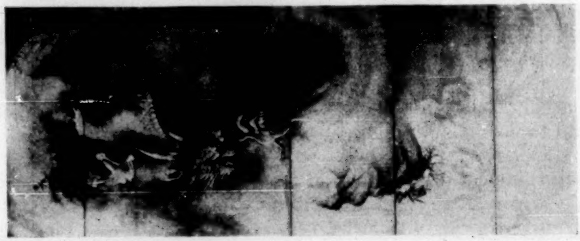
[3] Anesaki. "Buddhist Art in its Relation to Buddhist Ideals," Boston, 1915, p. 2. *For Lao Tsu*, see Kakuzo Okakara, "The Ideals of The East." London, John Murray, 1905, and later editions.

THE FIRST COSMIC THEORIES.

Zoroaster (Zarathustra), 1000 B. C. The Universe a mixture of Good and Evil Forces; [4] One supreme god, Mazdah, the God of Light-Fire. The Hymns of the Vedas.[5] The Earth as man sees it is only a passing phase in the creation and destruction of innumerable worlds. Hindu cosmologies with millions of ages of human life.

Homer and Hesiod. To them we owe much of our information of social forms and the actual beliefs of the ancient Mediterranean world. With Homer, as later with Shakespeare, we find the reflection of men's thoughts about life and nature. Here too arose the Cosmogonies of the ancient Greeks.



Kano Yeitoku—Japan 1543. A traditional representation of The Dragon as the Spirit of Life and Nature. Original in the Boston Museum of Fine Arts.

Lao Tsu. 604 B. C. To Lao Tsu the earth was a rhythm, but its way a mystery; the ultimate reality is Spirit. He is the founder of Chinese Mysticism. The tremendous dragon sweeping the air is the symbol of the inevitable and incessant power of Change. But in the mean time other social forces, other races and other social habits were in the world. Among the more practical, and if the truth be said, the less abstract and less imaginative peoples arising about the lands adjacent to the Mediterranean Sea, a far more human and objective explanation was desired. The war-making, ship-building, and restless races which eventually grew up into those we know as the Greeks and Egyptians evidently found more practical explanations for the earth. To them we must ascribe the virtue of taking the raw objective facts of nature and endeavoring to create a science out of them. That their mistakes, their misapprehensions, were very great is now another matter; it was primarily a difference in perspective. So then we find in the Greek and the Mediterranean culture:

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[4] It would be interesting to know to what extent we may ascribe to Zoroaster the idea that nature itself may be evil.

[5] There appears some confusion as to the actual connections of Zoroastrianism with the Vedic Hymns. See Sarton, George, "Introduction to the History of Science," vol. 1, p. 60. Carnegie Institution of Washington, Publication no. 376.

THE RISE OF NATURAL SCIENCE.

Out of the array of those whose names and ideas crowd upon us we may select the following as expressing points of most importance for their connections with modern ideas.

Anaximander 545 B. C.; *Anaxagoras* 428 B. C.; *Herodotus* 425 B. C.; *Plato-Aristotle; Eratosthenes* 192 B. C. Out of these men came the primitive conceptions of evolution; the conception of a vortex theory of earth creation (Anaxagoras) which appears to be a crude anticipation of the Nebular Hypothesis of Laplace over two thousand years later.[6]

Herodotus, 425 B. C., marks a transition into coördinated scientific ideas; something akin to schools or academies of science. He is not only the father of history, but he seems to have appreciated the facts of fossils, prehistoric lake villages, as integral parts of history. Herodotus described fossils from Egypt, and pre-historic Lake Dwellings in Macedonia.

With *Plato and Aristotle* human thinking emerged into the two types of approaches to nature which have marked that study ever since: the idealistic and the practical-observational.

Aristotle, 322 B. C., put the conception of the ultimate nature of matter into elements; Earth, Air, Fire, Water and the Ether. He appears to have been the first man to try to estimate the size of the earth, but here he was far surpassed by the first great geographer, Eratosthenes, who measured the circumference of the globe, using latitudes and distances, and obtained the figure of 7,850 miles; only 50 miles out.[7]

But as it appears to the present writer, the great background of this ancient Greek science, in so far as it is concerned more strictly with earth science, was the geometric work of Euclid and of Archimedes (B. C. c. 300). What that work amounted to was essentially this: they reduced what the modern scientist calls "space relationships" to definite scientific basis. They coördinated lines, spaces, points, directions, spaces, whether upon paper or upon the surface of the earth, but above all in men's minds in such a way that even today we use their conceptions of three dimensional space, and the mathematical formulas associated with them, for our science. Until the work of these two men had been done any such thing as measurement of the earth as to size, shape and form was guess work.

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[6] See Sarton, op. cit., vol. 1, pp. 128, 169 et passim.

[7] See Sarton, op. cit., p. 172, vol. 1.

Archimedes too discovered a fundamental law of nature in the principle of the floating mass displacing a mass equal to itself in the medium in which it floats.[8] This principle, seen in icebergs and so on, is obviously of primary importance in the modern discussions as to the foundations of the continents, and the problems of their support.

PASSING OF THE CLASSICAL WORLD.

The great development of Greek science, with its unquestioned accumulations of facts about nature; then its seemingly sudden collapse, has always excited the speculation of scholars, since there is, as our modern world well knows, a compelling force about science. Why did not the followers of these men whose names we have just been considering, carry on a message, make other great discoveries and achieve a great physical science? When we attempt a comparison of the science of our world with that of the ancients we see first that the Greeks with all their learning, had not brought their sciences around to any effective methods; in fact we may say they had no methods. We shall attempt later in this discussion to show what happened in the field of earth science just at the moment that some definite methods were discovered.

Secondly there is such a thing in life and in civilization as a climax, a time when certain sorts of human culture seem to reach a culmination of their energies and are unable to make further progress. The classical world gives an example of this. Few civilizations have been subjected to a greater strain than that which struck that old Mediterranean world. There for thousands of years its various cultures had struggled together, producing eventually the great religions of Asia, Palestine, Greece and Rome with their inevitable conflicts in human society. It is, apparently, one of the fatalities of history that supreme religious conflicts must be fought out in the most highly developed civilizations, since they strike so deeply into the philosophy of life. The gradual oncoming of the conflicts of those old religions does not always appeal to us perhaps with proper force, yet there they were boring into Greece and Rome. It was the profound tragedy of that old civilization that its mentality and culture were built up over two social aspects which the growth of learning and science would inevitably destroy. These were human slavery with its inhumanities; and a degeneration of religion which at the end was hardly more than a thinly veiled system of animal sacrifice and of human prostitution. In Rome worship of the Emperor, who was always exalted to a god, stopped any possible spiritual growth, and certainly could not permanently satisfy any man possessed of a serious intellectual interest in life, or in the make-up of the universe about him. All of it was accompanied by a cynical brutality and callousness which made the sacrificial aspects of the old religions intolerable to persons of a nobler and keener nature.

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[8] See John Joly, "Surface History of The Earth," Oxford, 1925, p. 37.

It was this apparently which roused the great *Lucretius* (93–55 B. C.) to open revolt. Lucretius was one of the world's restless spirits who seem to feel to an unbearable degree the conflict between accepted traditions, and life as it actually is. He derides in angry and vehement protest [9] the old religion with "human life foully prostrate" under systems of cruel and bloody sacrifices; with its "hideous aspect lowering upon mortals." He denies the divine creative power and its ability to create "out of nothing." Lucretius is the first [10] great agnostic, scientific sceptic, and materialist-mechanist to appear in the intellectual history of Europe. At one sweep he would wipe away the old gods and religions and set up in their place a world and a universe built up out of atoms and purely physical forces. He compares his teaching to the bitter draught, disguised at the rim of the cup with sweets, by which physicians induce children to drink the healing medicine.

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[9] "De rerum natura," lines 62 ff., trans. of H. A. J. Munro, London, 1920.

[10] He claims to be a follower of Empedocles (490 B. C.).

Opposed to him was *Cicero* (106–45 B. C.). He takes issue with Lucretius and bases his protest upon the great conception of a conscious design in the plan of nature. He was a deist, not a materialist. There is something peculiarly modern in the mutually contradictory character of these two men and their respective efforts to find a solution for matter and life.

Against them both appeared a man, *Seneca* (d. 65 A. D.) who in some respects was the most modern of the three. In his impassiveness, in his determination to get at the truth, Seneca set himself with Roman practicality to observe nature for himself, as well as to discuss the opinions of other observers. In his "Quaestiones Naturales" ("natural questions") he described an earthquake, distinguishing three types of motion, "succussio," "inclinatio," "vibratio," which may be translated into shaking, bending of position, and trembling. These correspond to modern observations of earthquake action. Into this unstabilized group of ancient cultures was cast the Christian Church to force social and intellectual readjustments, and effect one of the stupendous revolutions of history. It was an irrepressible conflict in which the old pagan civilizations were left with no central point of cohesion. Greece was gone, crushed under the power of Rome. Rome had become strictly utilitarian, engaged in the practical process of crushing out all races, nations and intellectual forces which did not at once bow to her obedience. In Rome it seems to have been a greater thing to parade conquered victims in the Arena than it was to produce a great intellectual idea. It was brutality raised to a science.

In all of this society the only movement with permanent vitality in it was the Gospel of Christ. It not only had a new message, that of love instead of force, but it had something distinctly practical in it that was of tremendous effect. Christianity is emphatically a social religion; it is for the people and consequently it faced a social problem, that of justification of itself. It was moreover an institution, an organism with life in it, so that if it was right and other religions wrong it had to prove it by taking its message out into all walks of human society. That is what its followers actually did. They propagandized, they criticized when to do so was to risk death; they demonstrated, they gave examples of their teachings so powerful that the old order gave way and Christianity inevitably grew into the stronger force. In the course of the ensuing social readjustments there was lost to the old pagan world, as expressed by Walter Pater,[11] "the prize of a cheerful temper on a candid survey of life." This cheerful temper went elsewhere and in doing so took the hopes of men and women along with it. Whatever force of science may have existed among the Greeks went out in an eclipse; by the time its forces might have collected themselves together once more the world was off to another track. It was not until twelve centuries later that Thomas Aquinas, with other medieval scholastics, rediscovered the ideas of Aristotle and supposed that thereby they had found the final key to fix man's relationships to both world and spirit.

Origen. Hence the only real systematized learning possible during the first generations of our era was shifted with intense suddenness from Plato, Aristotle and Lucretius to the elaboration of Christian theology. The conspicuous figure here, in the second century of our era, was the great Alexandrian philosopher, mystic, theologian and voluminous writer, Origen (A. D. 185). He deserves our attention because out of the old learning, the new Christian Gospel, and the changed outlook of the world, he endeavored to construct a new science, that of theology. This was not simply the only systematized learning possible at that time, but its energy was carried into Europe, to control the stream of men's thoughts for centuries to come. It is one of the most powerful coincidences of human history that the vast migratory impulses of the various races and tribes of northern Europe, which broke so heavily upon the Roman Empire, should become appropriated with the journeyings of the Christian missionaries. In all of the resulting social chaos the most powerful movements in society, or at any rate those of the most powerful efforts at reconstruction, were naturally to be found in the Christian Church and in the efforts to erect new political states out of the wreckage of the Roman Empire.

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[11] "Marius the Epicurean," chapter XXII.

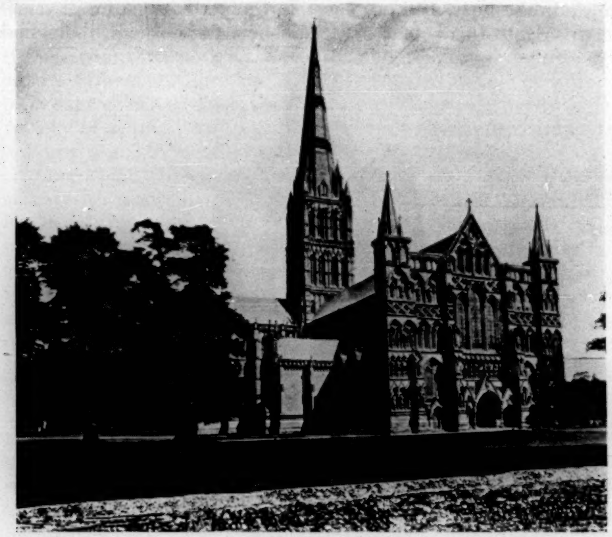
It meant the passing of an ancient animal-social culture, that of the Mediterranean region, and a new one just arising, that of north Europe, out of the nations along the Atlantic Ocean, the North Sea and the English Channel.

We do not look at this movement, or rather this collected series of movements, as geological, but surely they partook of a profound natural background. What would be the next great impulse in the relations of man to his physical-universe environment?

THE MIDDLE AGES.

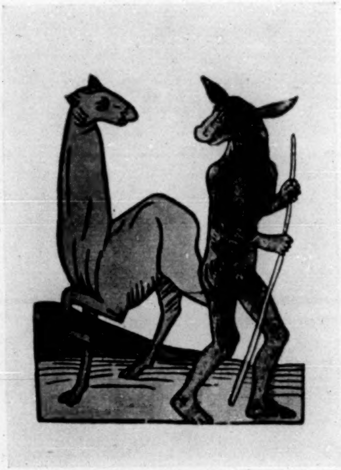
Fortunately here we are on purely historic ground; the answer is written for us. Just as men of previous ages had come under the power of various sorts of energy, so the men of the Middle Ages fell under the spell of another type of energy, that of the supernatural. This was not simply a shift in the field of facts, of data, but represents one of the great changes in social perspective which from time to time sweep over human society. The Greek Science stands between the efforts of the ancient world to find a super-power in the universe, and the efforts of the Middle Ages to find a formula by which earth, man, the destiny of all things might be explained. But physical science has at least this much in common with theology, that it must become eventually a social enterprise. It demands, in other words, a great base foundation in the mentality of men and women or it will never grow beyond the stage of something esoteric; something too remote from the usual run of civilized life to survive for long. Science, whatever else it may be, is a perspective, a point of view; and the great enterprises of the centuries we call collectively the Middle Ages were not, and could not become scientific. The point of view of what was to grow into European society had shifted its position. Hence perhaps we find here the explanation of why it is that accumulations of facts, such as Greek science for example, seem to be "lost." Is it not that for the moment their full importance, or their ultimate significance, is unrecognized, and so they are forgotten?

The supreme quest of the Middle Ages we must admit to have been a tremendous thing, that of bringing all possible human knowledge, all science, all society to bear upon the problem of man's final destiny. Hence the earth was conceived of as being the center of the visible universe. To this was added one of the most seductive of all systems of philosophy, that of Aristotle. Men fell under his spell, for they saw in it and its bosom companion scholasticism, the long looked for key to the riddle of life, and it was not observational-experimental, so that a certain perspective had to be upheld. If astronomers sought to explain the heavens they were told in effect that the cosmos was not subject to human investigation. Other naturalists were in the same position. It was not, we may take it, that earth and star were beneath notice, rather that men of science were presumed to be taking the wrong road to their understanding. Whatever science there was manifested itself first of all in one of the most splendid achievements of human genius, that of the great Gothic



Salisbury Cathedral. Thirteenth Century.

cathedrals. Here the triumph of mind over matter; the realization of great and beautiful visions; the genius of the architect, the engineer, the vast and insoluble dreams of poets and thinkers were all together raised up into one of the most exalted heights reached by man's spirit. Those cathedrals are, and were, humanity's tribute to the energy of existence; Something which will endure forever, first in this world and again in the next, and expressed in the perfection of a physical form. But other sciences were pushed into corners. Plagued by virulent diseases, harried by long wars, alternately fired by almost superhuman zeal in the crusades only to sink again into depressions of poverty and the fear of death, men sought to find some supreme antitoxin to overpower death and grant eternal youth: The Philosopher's Stone.

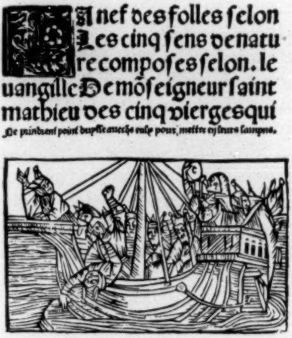


Mediæval Natural History. Onocenthaurus and Orasius (British Museum).

But the great obstruction in the path of science in the Middle Ages and its scholasticism, was that men did not know nature. In their efforts to put together a science which should include all of human knowledge, they forgot that to know nature one must study physical facts at first hand. As a medieval alchemist is reported to have said, "To make gold, one must have gold." So to possess nature, one must observe nature. One must observe, classify and identify, and this was precisely what was neglected. But this is at the bottom of all physical science, and for it the time was not ripe. So that whereas the Greeks had overemphasized natural forces and made them into gods, the scholars of the Middle Ages in Europe went to another extreme and neglected to observe nature almost altogether. Other centuries were yet to pass before it was realized as a social necessity that men need a great variety of approaches to truth; and that these efforts may be put into some kind of a union.

Out of all this welter of the Middle Ages grew then so strange an assortment of illustrations of natural objects that one hesitates to bring them forth lest he be suspected of a desire to be humorous. Aldrovandus, Athanasius Kircher and others of the medieval writers on the things and objects found in the rocks and physical world, offer such a mixture of actual objects, pseudomiraculous freaks; such a medley of the real and the impossible that on repeated reading of their tracts it seems difficult to believe that they should not have known better.

Among other social phases of the history of Europe during that time were the great popular delusions about the end of human life. In the absence of actual data about life, any age will apparently fall into these popular delusions. And among the most obvious, or what now seem to us as such, was the fear of the end of the world. As the year one thousand drew on it was widely anticipated in Europe, especially in continental Europe apparently more than in England, that the end of the world was at hand, for it was to be the Millennium. There was magic in the name of thousand, and old prophecies were brought forth to show what was to happen. A considerable literature has accumulated in regard to this, much of it of a spiritualistic-pseudomagical nature. When the year one thousand passed and nothing happened it was then recalled that it was to be the thousandth year from the destruction of Jerusalem, so that 1500, or about that, was set to be the fatal time. We have here the outburst of forerunners of all the Millennial Dawners, Millerites and others who believe that the destiny of this earth is at an appointed time to fit in with some of the arbitrary divisions of the human clock. How deeply this fear of death, judgment and world end was planted in society may be observed in Michael Angelo's "Last Judgment." Huge, chaotic, vast in its conception and execution; barbarous and yet terribly imbued with energy this dying conception of Medievalism still endures as one of the most popular, most typically human of all philosophies of earth destiny. Art critics are not apparently at one in the valuation of this work, but there can be little doubt as to its proper position in the intellectual development of European civilization. It has often been observed of course that in spite of, or perhaps because of, the very intensity of ecclesiasticism, there was a most extraordinary amount of satire and caricature within the Middle Ages. Especially was this the case towards the end of that epoch of human history, when the Middle Ages seem to have come into a state of cynicism and disillusion. One of the widely circulated books of the time was Sebastian Brant's "Stultifera Navis," or "Ship of Fools." This ran through many editions; was translated into French, and it is from the Paris edition that we have here an illustra-



La nef des folles ſelon
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Brant's "Ship of Fools" (Paris Edition. 1501).

tion. Its theme is the eternal folly of humanity; its moral the shortness of human life. All the agelong fools are here afloat in a ship whose pilot and steersman is the Fool in Cap and Bells. His passengers are the fops, the misers, the bibliomaniacs, the seekers after their lost vitality, the rowdy students; all in short of the grand procession of all the weaknesses and frailties of mankind.[12] Yet it is the Fool himself who warns that the world will end in chaos and destruction unless we listen to the voice of moral and religious truth.

THE NEW LEARNING.

The sixteenth to the eighteenth centuries mark another of the great turning points, not only of history in general, but particularly the history of science. First of all in the change of perspective; this was for the moment of more importance than the mere accumulation of further facts. This change is shown nowhere better than in the England of Elizabeth.

The Age of Elizabeth. This woman with the stuff of a Tudor King in her every fibre passed suddenly, upon the defeat of Spain, from the position of a queen fighting for her life to that of one of the most powerful monarchs in Europe. She raised England to a World Power, and in so doing created a new social order. Her navies swept the seas bringing quick expansion of wealth, the rise of the commons to affluence, with the determination to enjoy life to its uttermost.

Whereas formerly the common people had listened to the recital of the "Lives of the Saints," they now beheld the lives of the sinners and found them more engaging. Just as the taverns of London had echoed to the cynical songs of the wandering, vagabond medieval students of Oxford and Paris, the Mermaid Tavern now witnessed the influx of students who had other occupations for their minds. Drunken, dissolute, riotous as they were, yet like the roistering spirits of our own time, they were filled with the full freshness of life as it is, not as it might be imagined in some other world. Their plays sweep the ranges of life in no mere feeble impurities, but with rushings of a wild age of new found freedom and soul-stirring discovery. Compare the old Morality Plays of the Medieval Church with Green, Marlowe; Hamlet and Falstaff with the mysteries of sin and penitence, and the change is like a blast in the face. Elizabeth's great nagivators, Drake, Frobisher, Willoughby, circumnavigated the globe, or sought new routes to India, Greenland and the Polar Ocean. These sea captains returned home with strange and fabulous tales of new lands, new visions and astounding deeds of heroism. The earth, the seas, even the very atmosphere were made to throb in unison with human life. The effects of this stimulation to men's minds we must believe to have been as exciting, as energizing as our own age's discoveries into the mysteries of the universe. All of this deeply affected the development of science. This age marks the flowing of new sap in the idea that the relations of mankind to the physical universe, to the earth itself, are subjects which should be open for investigation without the penalty of being burned at the stake. There was yet a long road to go before this aim might be realized, but this one thing stands out clearly enough, that the thinkers of Europe had set their faces to another path. Henceforth for them the most important task was to investigate man and his universe at first hand.

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[12] The edition published at Bâsle, 1497, is said to contain a reference to the discovery of America.

One man stands out here with unmistakable emphasis: Sir Francis Bacon.[13] "His greatness consists in his repeated insistence on the facts that man is the servant and interpreter of nature, that truth is not derived from authority, and that knowledge is the fruit of experience." With the widening of men's affairs came a rebirth of interest in nature and in the meaning of the earth. It is certainly one of the most amazing contrasts of human history that just at the time when the great convulsive religious wars of Europe were dragging civilization down to ruin and despair, the minds of men should turn anew to the problem, the efforts, to try once more to read the riddle of the earth. Perhaps it was because of the apparent hopelessness of society at that time; perhaps the renewed uprush of one of the most fundamental of human interests, may be the answer, but this age brought forth a new crop of efforts to find the meaning of the earth. So that there came into being a group of what we may call, in distinction to the earlier group of Zoroaster and others:

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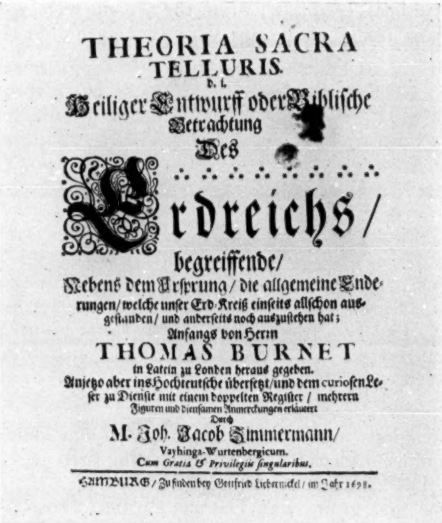
[13] Said to have been "the wisest, brightest, meanest of mankind."

THE LATER COSMOGONISTS.

Just as Greek science was preceded by the birth and development of theories of cosmogony, so our modern scientific culture was preceded by a group of men, quite numerous in Europe, who were captivated by the desire for more knowledge of the earth. But there was this difference. The Early Cosmogonists were assisted very little by what we may call science; their inspirations came from mysticism, spiritualized



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Figuren und dienſamen Anmerckungen erläutert
Durch
M. Joh. Jacob Zimmermann/
Vayhinga-Wurtenbergicum.
Cum Gratia & Privilegiis ſingularibus.

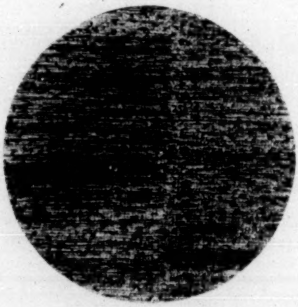
HAMBURG/ Zu finden bey Gottfried Liebernickel/ im Jahr 1698.

German Edition of Burnet's Sacred Series.

visions of the endless chains of our human imprisonment in physical bonds, and they sought a way out, an explanation. The Cosmogonists of the seventeenth and eighteenth centuries felt another impulse; that of the earth more completely for its own sake. They fastened their attention upon the earth as it is actually displayed in physical features, and sought new formulas for the explanation. These formularies fell into a stereotyped shape and became known as "Theories of the Earth." These theories were of such a character that they may very properly be separated into two definite types, as follows:

A. Sacred, or Theological Theories.
B. Pagan, or Scientific Theories.

The distinction is important for the reason that the first type were based designedly upon old Jewish and the Christian, that is Biblical, tradition; while the second were with equal definiteness based upon purely physical grounds regardless of any religious foundation. Each group was sincere; each had magnificent ideas for they were dealing with a tremendous subject, The Creation of the Earth.



First day of creation from Burnet's Sacred Series.

In the first group was Thomas Burnet whose work was first published in Latin about 1680.[14] It was translated many times and we have illustrated here a copy of the German edition of 1698. The original Latin title page is elaborate; translated into English (in part only) it reads, "The Sacred Theory of the Earth; containing an account of the Original of the Earth, and all the general changes which it hath already undergone," etc. In it Burnet gives illustrations of the days of creation; explained how the earth had a perpetual spring before the Flood; the great water foundations; the transition from Chaos to an orderly globe, and gives in addition a prophecy of the future destruction of the earth by fire. Here undoubtedly he was influenced by the Book of Revelation of St. John. Burnet's work is full of the most spectacular writing, exalted imagery, minute details; but it is, when not based upon actual Scripture, a subjective effort. It is as the author in fact said it was, a sacred, not a physical, theory. The work had a most extraordinary popularity, and unquestionably was of a very serious influence upon the minds and lives of subsequent generations. The writer of this purchased in Philadelphia some years ago a copy of an edition translated into English and published about 1825.

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[14] Charles Lyell, "Principles of Geology," vol. 1, gives "between 1680 and 1690" as the date.

Of totally different character were the "theories" written by purely scientific men such as Buffon, whose work met with the disapprobation of the Sorbonne, and was in form at least retracted.[15]

Another, less known, was by Guettard, whose efforts are described by Sir Archibald Geikie.[16]

But the writers of the first group, the "Sacred" type, had all the best of the argument. In the first place the spirit of the constituted authorities was not yet ready to yield to the new order. But more than this was the unquestioned fact that at that time the accumulations of fact as well as direct observations about the earth were not enough upon which to construct a truely scientific theory. That was to become the work of the men at the commencement of the nineteenth century. The time for the birth of a real science of the earth had not arrived, in either social perspective, or in data. Yet we should miss the ultimate significance of all these various theories if we fail to see that they foreshadow some of the most complex intellectual movements of later generations. There are varieties of the human temperament which express themselves in various ways; nowhere more so than in the relations of man and his natural environment. Men divide, as did Lucretius and Cicero, over the relation between a purely rational explanation of life, and other explanations based upon theological ideas of creative design. The efforts of the better type of eighteenth cosmogonists were towards the finding of some theories which would unite the earth, man and Creator into a system of things which would satisfy both the intellectual and religious instincts. That they failed, as they undoubtedly did, was due partly to the delusions of their time, but more to the enormous difficulties inherent in the nature of the problem, difficulties from which we of today have by no means separated ourselves.

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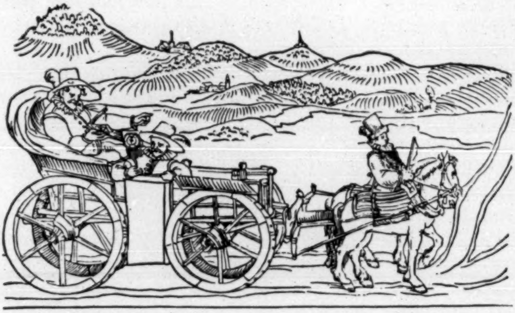
[15] Sir A. Geikie, "The Founders of Geology," London, 1897, p. 12.

[16] Idem, pp. 12 ff.

Nor should we neglect altogether the influence of these problems upon the literary products of that age. How much, if at all, Milton, Bunyan and others were directly influenced by the same ideas that influenced Burnet the present writer is not qualified to say; yet these earth theories undoubtedly bit deeply into the spirits of men, affecting both life and science.



Surveying while riding in carriage (Pfintzing, Methodus geometrica. 1598).

The generations of the period from Elizabeth to the French Revolution witnessed actually a great deal of preparation in science, and of quiet achievement.[17] Maps were made, of topographic character rather than geological; the use of surveyor's compass and other instruments became well known.

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[17] Nicholas Steno (1638–86) illustrates the futility of serious physical science investigation at this time; Steno understood and portrayed the nature of sedimentation etc., but he was too far ahead of his time to bring to a definite conclusion any earth science.

But during all these years a leaven was working, so that the ideas and discoveries of isolated investigators in astronomy, physics, geology and in plant and animal life were waiting only some great social readjustment to bring these varied lines of thinking to a common focus. The trigger which set off the explosion was the fall of the old French Régime and the Revolutions induced in men's mental attitudes by this overturn. Science at last was about to become a social energy. Hence the last years of the eighteenth century and the first few years of the nineteenth must always remain one of the most absorbing stages in the history of Europe. Whether it was the extraordinary stimulation of new social movements, or whether rather it was that a different atmosphere made a more open attitude towards science possible, is a question open no doubt to argument; but there is no question as to the extraordinary outburst of interest in the construction of the earth. The new chemical elements discovered; the open and stimulating interest in nature, in mountains, especially the Swiss Alps, and in rivers, forests; and most significantly of all perhaps in the nature of the rocks of the globe, all took the place of "theories" distorted by wrong perspectives and speculation. Men altered their visions of the kingdoms of the earth, and of the kingdoms of nature at the same time. They seem suddenly to have made the grand discovery, for which apparently we have been waiting so long a time, that all of the human strivings, the deep and often hidden efforts at investigation, could be made to bear a real fruit, having a genuine place in social history. This was strikingly true of the celestial vision. Where his predecessors had walked with steps clogged by dangerous pitfalls, the Frenchman, Laplace, was able to move in safety. He formulated out of his own work and that of the germs of ideas held by various philosophers and astronomers, a "theory" of the earth's origin which captivated men's minds. The Nebular Hypothesis of Laplace is, that the earth was formed by the slow cooling of a vast superheated nebular mass of gas, first to definite volume, then to a liquid, and so to a globe with a still liquid interior and a hardened crust to sustain its surface, with its atmosphere a tremendously active accumulation of acids and gases, and so eventually to a globe.

The hypothesis is in fact a theory of earth evolution. In it Laplace showed the conception of a progressive succession of stages of birth, growth, and at last a mature state in the history of the earth. Other theories have been advanced since; by Chamberlain and Moulton, by Jeans, by Einstein and others. Yet the Laplacian hypothesis, while not generally accepted by geologists, is still the great popular conception of the earth, that is, a globe with a liquid core, or center, of uncooled original molten matter, with a wobbly and uncertain crust. Laplace's ideas hold a unique position in the history of earth theories because they mark the first great expression of an evolutionary development of our globe. He stimulated men's minds anew to the grand conception of an earth growing within its own forces, its own matter taking definite form, through a prolonged and logically connected series of stages of physical development. Perhaps we do not always appreciate as fully as we should that physical evolution of the earth must, both in the logic of the case as well as in actual nature, precede organic evolution.

THE BIRTH OF GEOLOGY.

Neptunists and Plutonists.

At the opening of the nineteenth century three great fundamental problems of earth character were pressing upon the minds of students of the earth. These problems were not in themselves new, but they assumed what seems to be a sudden, newly acquired interest from the highly important fact that men were seeking explanations of nature from a scientific rather than from a theological perspective. This change of attitude is one of the various things which marks the profound social revolutions at the close of the eighteenth century.

These three problems then were:

1st. The nature of the rocks we call granite and basalt; that is, the igneous (heat) rocks.

2d. The nature and origin of the rocks we now call sedimentary; that is, limestones, the mud rocks, and so on.

3d. The real character and meaning of the shells and bones found in the rock masses; that is to say, the meaning of fossils.

At the time of which we now write nothing fundamental or basic was generally understood or accepted about either the origin of rocks, or the origin of fossils. There being little understanding of the atmospheric and water forces which break down hard rocks and turn them into new types of layers (strata), there could not be very accurate comprehension of either the actual life character of the objects called fossils, or of how these objects came naturally to be buried in the rocks. Likewise there was no generally accepted theory, or in fact any real comprehension of the fact, of volcanoes and other forces in connection with the interior of the globe as the seat of tremendous and continuous energies; so that we see, as an actual development of history, the prevalence of two schools of thinking and teaching about all rocks, and by inference any fossils found in them.

The Neptunists, who comprised the first group, held that all rocks, even granite and basalt, were formed from the action of water. More specifically as taught by the influential A. G. Werner of Freiberg, that they were precipitates from an original universal ocean spread over the entire globe from valleys to mountain tops.[18] *The Plutonists*, or second group, looked to an internal heat, or fire, for the origin of the rocks of the earth.

As was stated in an earlier paragraph, under the subject of the Greek physical science, the development of a real science of the earth must be built around actual physical observation and experiment.

At this time (about 1800) out of all the various names of investigators into the nature of rocks and fossils, three men are of particular importance. These are Sir James Hall for his discoveries in the nature of rock formation; and Brongniart and Cuvier for their work in the sedimentatary formations and the life remains found in them.

THE BEGINNING OF EXPERIMENTAL GEOLOGY.

Sir James Hall (1761–1832). Hall performed the first authenticated physical experiment ever made with the expressed intention of demonstrating, or repeating, some process of nature; in this instance the formation of different types of rocks.[19] What he did is simple enough today, but was revolutionary then. Hall placed samples of the rock known as "whinstone" in England, more familiarly known in America as "traprock," in an iron reverberatory furnace and by melting and cooling at varying temperatures and rates obtained artificially the structures found in the fresh lavas, and also in the hardened types of the crystalline or "plutonic" variety of rocks. Hall not only founded experimental geology by this work, but laid the foundations for the subsequent investigation of the igneous (heat) rocks upon a purely scientific basis. In addition to his work on whinstone Hall converted chalk into marble by heat and pressure, thus demonstrating the

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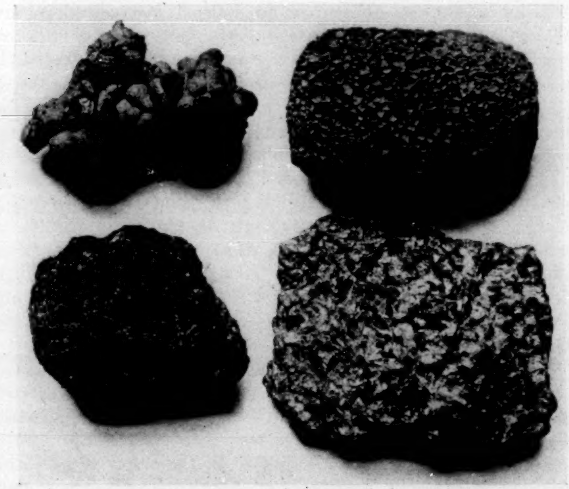
[18] Some popular account of this may be found in "The Founders of Geology," Sir A. Geikie, London, 1897.



Various phases of Basalt Lava and Gabbro (Trap-Whinstone).

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[19] Hall's accounts are well worth reading, and were published in *Trans. Roy. Soc. Edin.*, 1790 and ff. yrs. Some general account may be found in A. Geikie, "Founders of Geology." The present writer is preparing a monograph on this subject.

changes (metamorphism) by which sediments formed from water are profoundly altered by the energies within the earth. Later the Frenchman, Daubree,[20] demonstrated by actual experiments the natural formation of definite metamorphic types of rock structures by the action of forces acting generally within the globe, which today are an essential part of earth science. More lately Sorby, Zirkel, Rosenbusch and others, in both Europe and America, have so studied the actions of earth energies in the behavior of these igneous rocks, along with their varying chemical-physical character, that it is now possible to unravel some of the processes which are carried out beneath the earth's surface. *Fouque and Levy*[21] deserve particular mention for their production of basalt and other igneous rocks by purely synthetic processes. By fusion of the calculated amounts of the usual mineral oxides present in these rocks they made glassy, crystalline and various intermediate stages of actual naturally occurring rock types. Just as chemists have made synthetic *urea*, so experimental geologists have reproduced other kinds of nature's own products. The influence of all this work, carried out since Hall's original experiments, is of vast importance in the efforts to comprehend the earth. This work shows among other things that volcanic, and other heat energies, instead of being, as was formerly assumed to be true, simply casual aspects of surface action, are in reality exhibitions of tremendous, far reaching and fundamental earth behavior. By this work it is now possible to approach the extremely difficult subject of continental structures, the relations of the great oceanic depressions, the past land connections and other basic geological problems with hope of some ultimate success.

THE RISE OF PALEONTOLOGY.

The second great achievement of the men of the end of the eighteenth and the commencement of the nineteenth centuries, was the public proof of the real connections between fossils buried in the rocks and other formations, and the rock beds.

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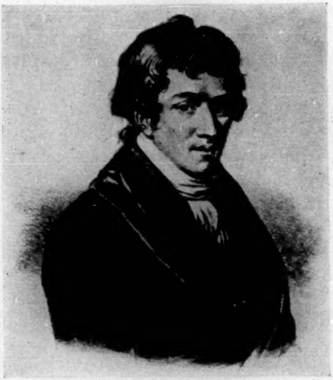
[20] "Etudes synthetiques de geologie experimentale," Paris, 1879.

[21] "Bull. de la Societe mineralogique de France," 1881, tome IV. Abstracted also in "Fremy, Encly. Chimique," tome 11, pt. 4, Paris 1884.

Brongniart, Cuvier, two Germans Fuchsel and Lehman, had shown that rocks and fossils bore definite relations to each other. For various reasons partly social, partly his own personality, controversies about fossils centered about the famous French naturalist, educator, and man of affairs, *Georges* (Baron) *Cuvier* (1769–1832). Born in the Jura mountains, he came later to Normandy. Here he encountered something which has been the stimulation of many European geologists and naturalists, the rocks and shores of Normandy and Brittany. He fell under their charm just as in England and Scotland others fell under the charm of Dover Cliffs, the shores of Dorset and the indented coast of Scotland. Later on at Paris, Cuvier dug into that most fascinating region the "Paris Basin," which is a veritable store house of past phases of earth history. Cuvier showed the real nature of the bones and shells dug up there. An associate of Brongniart, and following the work of Buffon, Cuvier was no man to be pushed aside because his work met with opposition. He showed for the first time I believe in history, that elephants of an extinct type once roamed over what is now western Europe, so that Cuvier definitely introduced past life factors into the study



Baron Cuvier (British Museum).

of the earth, thus destroying the old view that none of the buried animals found in rocks could be older than the Deluge of Noah. This was as much a revolution as were the discoveries of Hall. Each man by the evidences brought out into the open light demonstrated the truth of general forces, or factors about the development of the earth which previously were actually rejected.

EROSION, SEDIMENTATION AND STRATIGRAPHY.

But so far the really fundamental things about earth actions, earth forces and the origin of the major features of the globe had not been written out in a systematic manner. Indeed many of the general principles were not at all understood. To collect all of the data then at hand, to add other truth to them, to classify what Hall had shown, what Cuvier and others had demonstrated; to construct in other words for the first time in the intellectual development of society, a well ordered systematized foundation of fact and theories from which to try to understand the earth, was the work yet remaining to be done. This was the work of three men (James Hutton, William Smith, Sir Charles Lyell). The significance of their work, it is due to say, lay in their remarkable genius for diagnosis and for generalization. While others had made great discoveries; had keen mentalities and had produced fundamental results, these men went beyond those points. There comes a time in the growth of intellectual ideas when many things unite to bring about results which for one cause or another have not been fully understood. So it was at the period under discussion. So that in naming three men here as preëminent, it is not the intention to slight the works of other men; but as it appears today their genius was of a somewhat different order. It was time to write a new "Theory of the Earth" based not upon tradition, nor pure speculation, nor of isolated facts, but by an appeal to the forces which act generally over the whole earth. The man whose writings and work gave certain foundation to earth science was *James Hutton* (1726–1797). He published in 1795 his "Theory of the Earth." [22] Hutton was emphatically a student of, and a profound believer in, the ceaseless energies within the globe, and among other things was greatly moved by the all powerful erosion of the sea against the shores of the British Isles. There he saw in the sea stacks, or remnants of the former extension of the solid lands, the unquestionable evidences of ancient rock layers deposited in a remote time again being disintegrated and washed away, that they might again build up newer series of the rock beds of the earth. Hutton used the present as the key to the past, and gave speech to a formula which has passed into a geological proverb: that in the economy of nature there is discernible no trace of a beginning, no prospect of an end. By these and other ideas Hutton laid the foundation for the great idea known as "uniformitarianism" in the processes of nature. His great achievements lay in the demonstrations of what today

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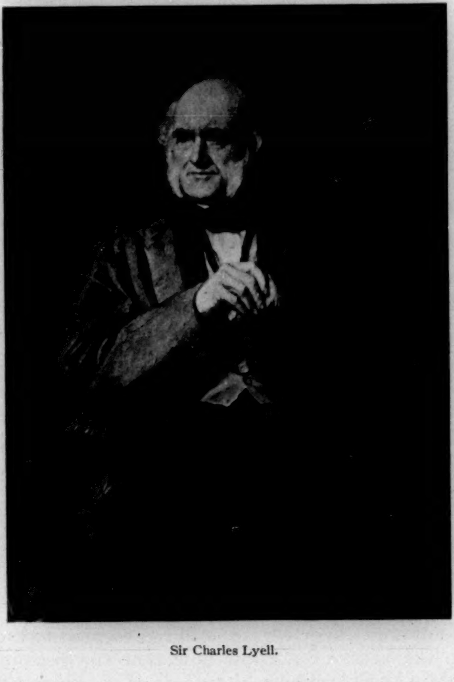
[22] "Theory of the Earth, with Proofs and Illustrations," by James Hutton, M.D., F.R.S.E., Edinburgh, 1795, 2 vols.

Holborn Head. Sea Erosion, Coast of Scotland.

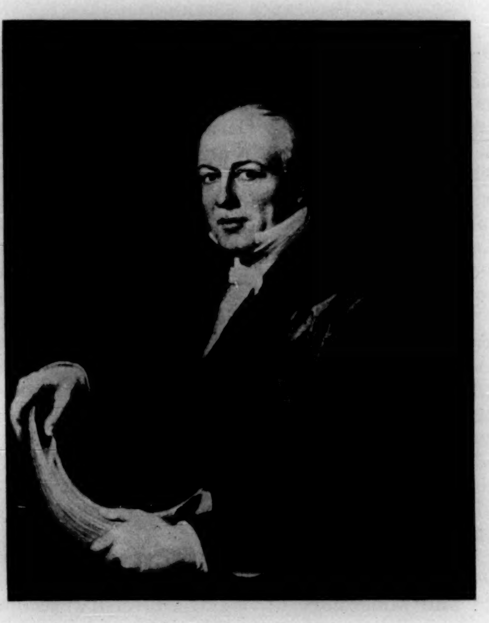
we call weathering (decomposition and destruction) of solid rock masses to soils; the fact of water erosion in river valleys etc.; the evidences of mountain uplifts with the immense body of sediments previously formed at sea and oceanic levels. He laid the foundations for a scientific geography (physiography); for a rational explanation of rock types, and their systematic arrangement. Hutton was a Futurist; he seems always in his writings to be looking to future generations to justify his work. He is justly called "The Father of Geology"; his work is a mine of geological ideas.

William Smith, called "Strata" Smith. Those who perchance have visited the charming old English town of Bath may have seen among its historic mansions a tablet to the memory of William Smith. He used the strata about Bath to demonstrate the fact of the original continuity of the old rock beds across the country. He made for the first time in history a map with all of the geological formations from the coals up to the chalks, with their fossils pictured, their types of landscape shown and their thickness. Smith gave definite form to the fundamental geological truth that these great rock layers of the earth represent an historic succession: known today as "the law of stratigraphic succession." This is the foundation of any constructive earth history.

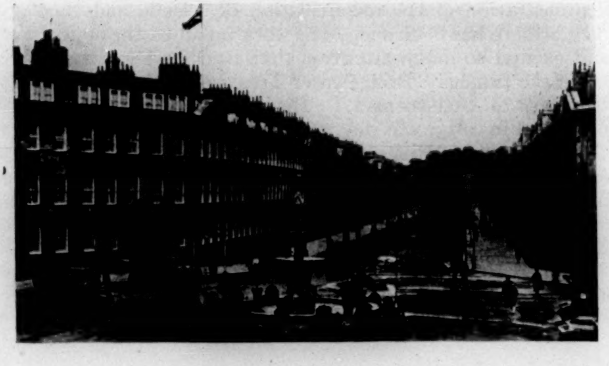
Sir Charles Lyell went beyond this to show that by the use of certain sorts of fossils, carefully studied in a statistical form, it is possible to arrange the life types in a quantitative manner, fix geological dates and, to the various strata as determined by Smith and others, assign a definite order over the world. Working upon a numerical basis first indicated by Cuvier and Deshayes, Lyell separated the formations called *Tertiary* into a definite succession called respectively Eocene, Miocene, Pliocene, Pleistocene, and pointed to the Eocene as the first "date," or rock series, in which we may find the fossil shells of animals (invertebrate) still represented among forms living in the seas. We know now that the percentage established by Lyell is subject to variation; yet his contention is basically sound. He marked the definite time when modern life started, fixed its position in the whole series of rock formations, and by so doing helped to raise paleontology from a purely biological aspect of geology to a vast key with which to attempt to write out in logical order the history of our earth. The methods thus established by this great group of scholars are those used today by archeologists, students of human paleontology and others who need to apply the statistical method to any form of physical history, involving animal or plant types. To this group must be added *Charles Darwin*, for although his work was not primarily geological he built upon ideas which involved earth factors. Darwin's work is too well known to need elaboration here. He marks the passing of the old group of European naturalists, for when Cuvier died Darwin had just graduated from Cambridge.



Sir Charles Lyell.



William Buckland, D.D., F.R.S.



Pulteney Street, Bath, England.

So that with the ideas of rock genesis as established by Hall and others; the successions of sedimentary formations as shown by Cuvier, Deshayes, Smith and Lyell; the evolutionary factors as introduced by Darwin, earth science was by the middle of the last century put at last upon a really observational and experimental foundation.

That all of these new and, in many respects astounding, ideas and discoveries could be given publicity without violent reactions was too much perhaps to expect. At any rate we know from actual history that these geological ideas were tremendously disturbing to a great many intelligent people. We are today in better perspective to appreciate the case than was true then. One must admit that merely to say that it is proposed seriously to write a history of the earth constitutes in itself a startling thing to attempt. Add to this the intense theological background hitherto regarded as essential to the understanding of earth and creation, and we see how easily misunderstandings, prejudices and antagonisms would and did arise. One man must be mentioned here for his scientific work, his fineness of personality and the extraordinary range of his activities.

Dr. William Buckland, D.D., Dean of Westminster Abbey, Canon of Christ Church, Oxford, the first Professor of Geology and Mineralogy in Oxford University; scholar, theologian, geologist, one of the founders of vertebrate paleontology; twice president of the Geological Society, Buckland is a demonstration of the reconciliation of science and theology if ever there has been one. His work inflamed the opposition, and excited so much attention that Buckland was moved to write the famous "Bridgewater Treatises designed to justify the ways of God to man." His own work in two volumes published in 1833, was devoted to "Geology and Mineralogy Considered with Reference to Natural Theology" and is a serious and scholarly work worth attention today. This is true particularly in America which is just about an even one hundred years behind the threshing out of that problem in England.[23]

The reactions of nineteenth century science to society may be seen in the poetry of Lord Tennyson; especially in "In Memoriam," "Locksley Hall"; in Robert Browning: "Bishop Bloughram's Apology"; and "Development"; and for its humorous side in the cartoons in the irrepressible London *Punch*.

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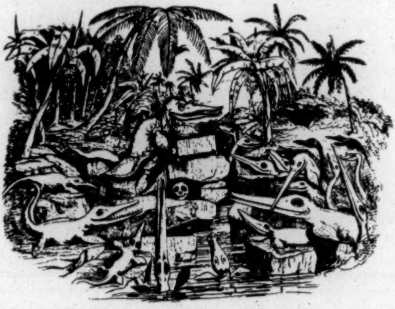
[23] Sir Charles Lyell, already mentioned, was a pupil of Buckland's.

In Germany and France other writers, such as D. F. Strauss, Ernst Haeckel, J. F. Renan, found in these astounding aspects of physical science opportunities for philosophical and theological controversy.

But it was not alone in society at large that there came repercussions from these new ideas about the earth and its physical developments. Some of the strongest of these influences were felt in other sciences such as astronomy and biology. In astronomy the discoveries of not only one, but several, times of world wide glaciation; the altogether unexpected and astonishing discovery of the fossils of trees such as willow, maple and similar temperate zone types, in the rock beds of Spitzbergen and other places in polar regions; the other evidences of prolonged and rhythmic variations of heat received from the sun at various times in the remote past of the earth, have all compelled some reconstructions of astronomical theories. Again the discoveries of the paleontologists, especially in the direction of entirely new groups such as the dinosaurs; the evidences of vast animal migrations among the mammals, as well as the problems of other animal and plant



"Awful Changes." Caricature of Buckland's paleontological discoveries from The Life and Correspondence of William Buckland, D.D.

distributions; evidences of mutations and similar important paleontological disclosures, have had revolutionary results in conceptions of earth and life.

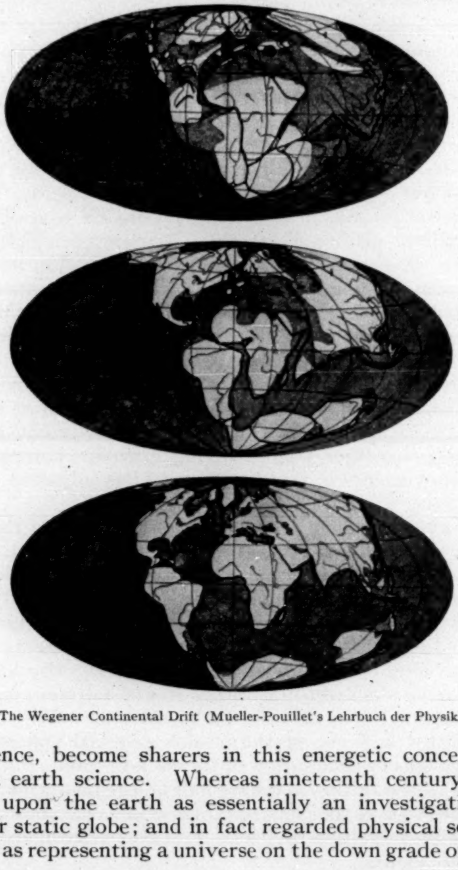
Evolution today means not simply developments of a biological nature, but of growths, changes and developments of the earth in a physical sense.

PHYSIOGRAPHY AND PALEOGEOGRAPHY.

From these accumulations of facts and theories of our earth as a dynamic, energetic and changing globe have come some new groups, or aspects of geological science. These are chiefly those subjects called physiography, paleogeography and geo-physics. These may be stated in simpler terms to mean first, the newer conception of geography as the explanation of land and sea forms, with the atmosphere, as connected portions of the various phases of surface modifications of the earth; of landscape as earth shaping, or of earth evolution. *Paleogeography*, or simply ancient geography, is the effort to picture not simply present geographic conditions, but that of a great many previous aspects of the surface of the earth. This study in its pictures reconstructs the life of the ancient seas, the developing phases of the continents, mountains, rivers, and finally the continents themselves. In this work the late Edward Suess of Vienna, de Lapparent of France, and many others since in Europe and America, have greatly invigorated the study of the earth. We have then from many different sorts of approach the vision of an energetic earth, not a static one. *Geo-physics*, perhaps the youngest child of earth science, has arisen from these vigorous conceptions. Problems of the relative densities and gravities of the various portions of the globe, on the lands and beneath the oceans; the serious problem of earthquakes, constantly of greater importance as towns and cities increase; efforts to read farther and deeper into the structures of the earth beneath the surface; problems of the distribution of oil, water, and other needed mineral resources now beyond human reach, are a few of the questions, both theoretical and practical, which it is hoped may be enlightened by the study of the earth from its energetic physical behavior. This is the field of geo-physics.

THE STABILITY OF CONTINENTS.

Just as problems of various conceptions of evolution have been developed from the study of the earth, so inevitably the continents themselves have gradually, in the course of geological science, become sharers in this energetic conception of modern earth science. Whereas nineteenth century science looked upon the earth as essentially an investigation in a fixed, or static globe; and in fact regarded physical science in general as representing a universe on the down grade of energy,



The Wegener Continental Drift (Mueller-Pouillet's Lehrbuch der Physik).

the view is now almost completely reversed. So that today we are both witnessing and sharing in one of the intellectual revolutions; a shifting of perspective towards the earth which marks another of the uprushing of new ideas, new efforts to read the mystery of our globe.

Undoubtedly there are definite explanations for this, but among them should be placed the extraordinary stimulations to every phase of human thinking caused by the discovery of radiant energies in minerals, rocks, waters, the other portions of the universe, and indeed penetrating into every aspect of life. In geology this has suggested great revision of previous ideas of earth evolution. The writings of John Joly, of Cambridge, and of many others deal with these problems. Among the most conspicuous of the recent theories is that of "continental drift," proposed by the German geologist, Alfred Wegener. Wegener conceived of a vast original mass of land, the *pangæa*, or parent continent. This, in comparatively recent geological time, split into various segments, which then under the variation in fluidity, or plasticity, of various portions of the globe, drifted apart to form the continental lands we see today. This theory of Wegener's seems to come into a direct contradiction to the other theory known as *isostasy*, proposed in 1889 by C. E. Dutton, that adjustments of earth pressures come rather from a sagging down and corresponding upward movements in the earth's crust: an adjusted, permanent balance.

We have come then a long way in our study of the earth. If this present effort has been at all a successful one, then it may be perceived that actually throughout practically all of the great long story of human efforts to read the earth it has been the study of energy. Whether that energy may have been ascribed at first to obscure nature gods, or to mysterious chance; or later to the indications of a ceaseless rhythm in the universe in general; or to the direct acts of a divine creator; to the atomic forces, we are still under the spell of the earth as the exhibitor and the platform of a celestial sphere which shows no signs of diminution of its life and force.

What of the future? What shall be the next great theory of the earth to take the place of others whose character we have in brief endeavored to review? To this question there may now be no answer.

In all of the prevalent chaos of society, and of philosophies, our ship is still afloat. Geology is a hopeful science; one which always by coming thus into intimate associations with vitality and energy, is powerfully stimulating and refreshing. Its followers take on new enthusiasms, new encouragement. In the energies of volcanic action, in those earth nerves of earthquakes, in the wide reaches of marine geology; but most of all perhaps in the visions of the geologically recent uprisings of vast mountains, fresh, ice capped, exalting and drawing increasingly our attention, we may renew our hopes, our faiths and our intense zeal to study again and again our earth. In its outlooks geology shares with astronomy a cosmic vision, with theology the problem of human destiny; these three, astronomy, geology, theology, are still the giant keys with which to unlock the doors to the riddle of existence.

Animal Drugs.—Hippocrates (460–370 B.C.) mentioned approximately 400 drugs, among which were at least 26 substances of animal origin, such as goose fat, ox gall, wax, and cantharides. Galen, six centuries later, described 820 drugs, including 180 of animal origin. During the sixteenth and seventeenth centuries, animal remedies were rapidly introduced into the materia medica. The collections in the Division of Medicine of the United States National Museum illustrate the various animal organs, tissues, and products which have found therapeutic application in the past. CHARLES WHITEBREAD (*Journ. Am. Phar. Asso.*, 1933, XXII, 431–437) describes 53 of the animal drugs in this collection, and the specific application formerly made of them in medicine. Since 1796, when Jenner introduced vaccination against smallpox, numerous contributions to the materia medica have been made from the animal kingdom, such as the glandular products and the hormones like insulin and epinephrine, and the antitoxins used in the prevention and the treatment of diphtheria and similar diseases.

J. S. H.

Conserving the Aroma of Cedar.—(U. S. Dept. of Agric. Clip Sheet No. 779.) Apparently cedar closets have not been constructed so efficiently as casual examination might indicate. The moth-repellent properties of cedar wood are due of course to the volatile aromatic oil that slowly exudes from the pores of the wood. Cedar lumber, being quite uniform in composition, liberates the oil vapors from all the surfaces. As a result, that fraction of oil expelled from the exterior surface of a cedar-wood closet is wasted so far as its intended moth-proofing action is concerned.

In order to prevent such an inadvertently misdirected dispersal on cedar oil FRANK RABAK, biochemist of the Bureau of Plant Industry, has developed a process for sealing and coating red-cedar lumber with paraffin. The problem was rendered difficult because of requirements such as the coating must seal only one side of the lining; it must be transparent so as not to hide the grain and quality of the wood; it had to be low in cost, easy to apply and quick drying. A final problem was to get a coating that would not become sticky when packed in the almost airtight containers in which this lining is shipped and stored.

C.

THE COSMIC RAY HODOSCOPE.

BY

THOMAS H. JOHNSON and E. C. STEVENSON.

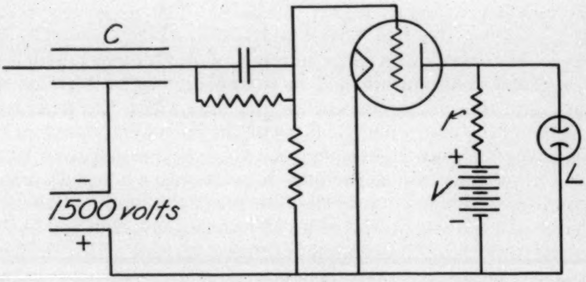
BARTOL RESEARCH
FOUNDATION
Communication No. 75

The cosmic ray hodoscope is an instrument for observing and studying the detailed phenomena of the cosmic radiation by making visible the paths of the penetrating corpuscular rays through a continuous region of space. The name has been derived from the two Greek words ὅδος, *track*, and ςκοπεω, *to view*. It consists of a large number of small Geiger Mueller cylindrical counters stacked in a two dimensional array or bank and thus filling, except for the interstices, the sensitive volume of the instrument. Each of the individual counters in the bank is connected through one stage of amplification to a neon glow lamp which occupies a position on a panel corresponding to the position of the counter in the bank. The discharge of a counter, initiated by an ionizing ray, thus produces a flash in the lamp to which it is connected, and with a similar geometrical arrangement between counter bank and lamp panel, a sequence of counters discharged simultaneously by one of the penetrating corpuscular cosmic rays produces an illuminated track. These tracks may be photographed or observed visually. The hodoscope therefore accomplishes to a limited extent the same purpose as the Wilson cloud chamber and it has the advantage of being continuously sensitive.

A simple circuit for amplifying a counter discharge and applying it to a glow lamp is shown in Fig. 1. The resistance r is chosen in relation to the characteristics of the amplifying tube so that, under normal operation with the grid at the cathode potential, the voltage applied to the plate, and therefore across the lamp, is small compared with that across r, and is less than the flashing potential. If, however, the counter C is discharged by an ionizing ray, the negative pulse delivered to the grid raises the plate impedance to a value which is large compared with r and the potential across the lamp rises to the flashing voltage. The current through the lamp is then limited by the resistance *r*. When the grid potential again drops to that of the cathode, the potential across the lamp falls below the extinction point and the lamp is again dark.

With a simple circuit of this type connecting each of the counters with the corresponding lamp, a flash occurs for every counter discharge whether it be initiated by a penetrating cosmic ray or by local radioactive radiation, and the long tracks of the cosmic rays are obscured in the confusion of the numerous unrelated flashes of the local radiation.

FIG. 1.

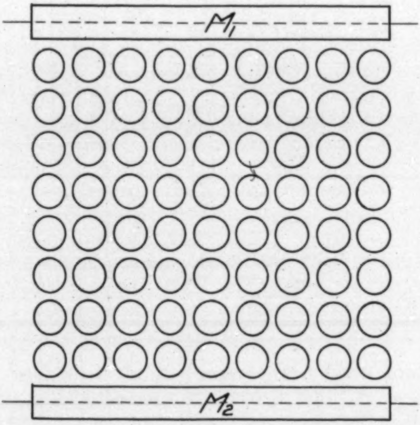


Simple circuit for producing flashes from a counter discharge.

In order to observe the cosmic ray tracks alone, without the disturbance of the local radiation, the coincidence principle has been employed in a control circuit which suppresses the flashes for all individual counter discharges except those occurring coincidently with the discharge of a master counter, M_1, Fig. 2, placed above the bank of individuals, or alternatively, with the simultaneous discharge of two master counters, M_1 and M_2, one of which is above and the other below the bank. With this circuit the instrument is thus able to distinguish between the cosmic rays and the local rays, making use of the unique property of the cosmic ray that it is able to penetrate and discharge a large number of counters. With the control circuit in operation, practically no flashes occur on the lamp panel other than those showing the long cosmic ray tracks and one can be quite certain that all flashes which appear to be simultaneous are actually produced by a single primary cosmic ray together with its associated secondary radiations.

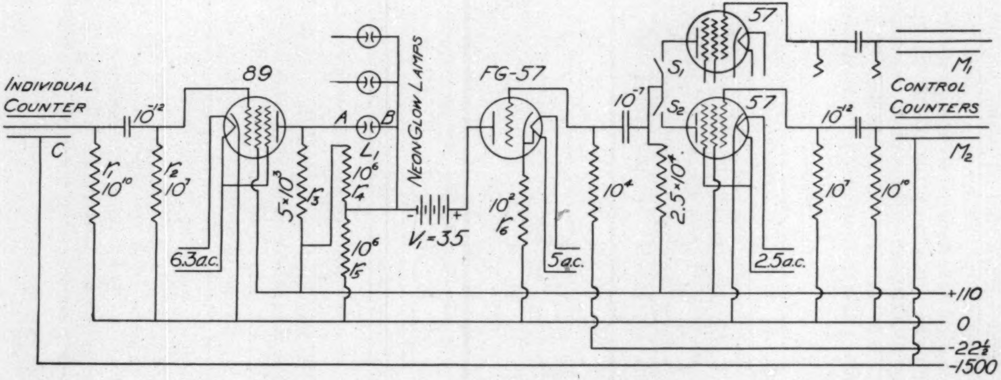
The complete circuit with the master counter control is given in Fig. 3, with connections suitable for amplifying tubes of the power pentode type such as the 89. Each of the flash lamps is connected in the output of the corresponding amplifier in the manner indicated for L_1, and the opposite terminal B of all lamps in parallel is connected through a thyratron (such as the *FG* 57) the grid of which is controlled by the master counters. By means of switches S_1 and S_2 this control is exercised by M_1, or by M_2, or by coincidences between M_1 and M_2 depending upon the closing of S_1, or of S_2, or of both S_1 and S_2, respectively. When the thyratron is made conducting by a pulse from the master counters, the common terminal B of the lamp panel is connected to the ground through the additional battery V_1, allowing those lamps to flash to which a simultaneous potential is applied at A. At

FIG. 2.



Geometrical arrangement of the 72-element hodoscope.

FIG. 3.


INDIVIDUAL COUNTER
C
r_1 10^{10}
10^{-12}
r_2 10^7
89
6.3a.c.
5×10^3 r_3
A
B
L_1 10^6 r_4
10^6 r_5
NEON GLOW LAMPS
$V_1=35$
FG-57
10^2 r_6
5a.c.
10^4
10^{-7}
2.5×10^4
S_1
S_2
57
57
2.5a.c.
10^{-12}
10^7
10^{10}
M_1
CONTROL COUNTERS
M_2
+110
0
$-22\frac{1}{2}$
-1500

Complete circuit diagram of the hodoscope. Capacities are given in farads, resistances in ohms, and potentials in volts.

other times B is maintained at a positive potential above that of A by means of a potential divider $r_4\, r_5$ of which the resistance is small compared with leakage resistances across lamps and thyratron but high enough that current through it is unable to maintain a discharge in the thyratron.

With amplifiers of the 89 type and lamps of the type G 10 having flash and extinction potentials of 80 volts and 60 volts, respectively, and with other circuit constants as follows, $r_3 = 5000$ ohms, $r_4 = r_5 = 10^6$ ohms, $V_1 = 35$ volts, $r_6 = 100$ ohms, the potentials at A and B are approximately as follows.

I. Under normal operation with no pulse from either the individual or master counters, $V_A = +5$ volts, $V_B = +55$ volts.
II. During a pulse from the individual counter not coincident with a pulse from the master counter, $V_A = +110$ volts, $V_B = +55$ volts.
III. During a pulse from the master counters not coincident with a pulse from the individual counter, $V_A = +5$ volts, $V_B = -35$ volts.
IV. During simultaneous pulses from both individual and master counters, V_A could rise to $+110$ volts and $V_B = -35$ volts. 145 volts across the lamp is therefore available and the flashing of the lamp is assured.

Two models of the hodoscope have been constructed. The first was a 36 element instrument built up in three sections of twelve elements each.[1] In this instrument the 27 triode amplifier was used and the counters were inserted into metal boxes containing twelve separate compartments. Each counter was thus electrically shielded from every other counter and no trouble was experienced from "pick up" discharges. The counter cylinders were 3 cms. long by 1.2 cms. in diameter. Figure 4 is a photograph of the complete instrument showing the lamp panel, the amplifiers projecting from the boxes of counters, and the various voltage supplies. The operation of this instrument was entirely from the 110 volt a.c. main.

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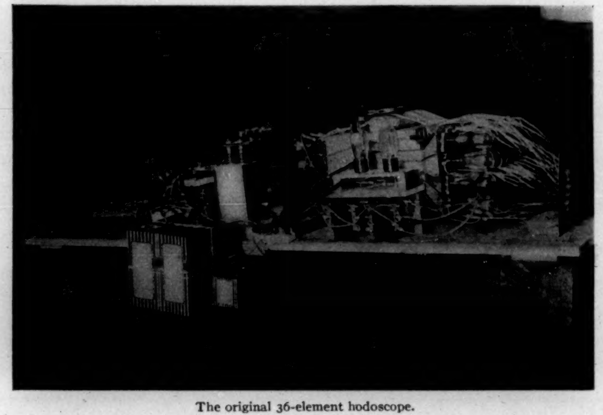
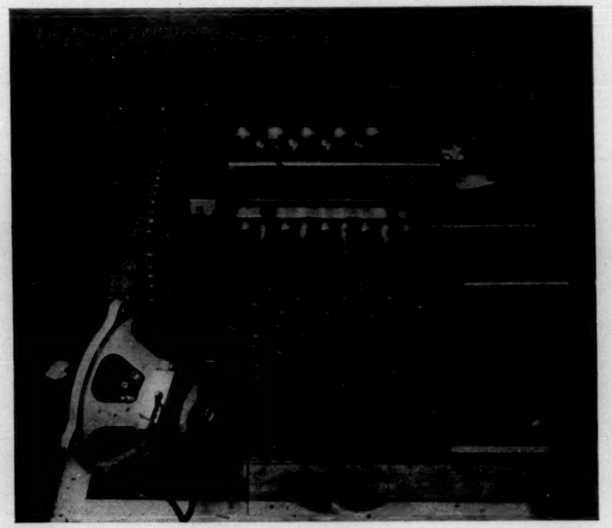
[1] This instrument was described and demonstrated at the Dec. 1932 Meeting of the American Physical Society, *Phys. Rev.*, **43**, 379, 1933.

FIG. 4.



The original 36-element hodoscope.

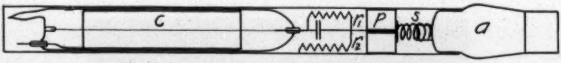
FIG. 5.



The 72-element hodoscope.

The second model, photographed in Fig. 5, was built for demonstration purposes at the Chicago Progress Exposition. It contains 72 elements and uses the 89 pentode amplifier. The individual counters are 4 inches long by 1 inch in diameter and each is mounted with its coupling condenser and resistors r_1 and r_2 in a thin aluminum tube. The dome shaped bulb of the amplifier projects into this tube and connection is made to the grid by means of a spring, Fig. 6. The plate voltage supplies in this case are taken directly from the 110 volt d.c. main and the counter potential is obtained from the rectified output of a transformer, controlled by a tetrode.[2] The high voltage unit is encased in the aluminum box shown at the right of Fig. 5.

FIG. 6.



Individual counter mounting. *C*, the Geiger Mueller counter; r_1, 10^{10} ohm resistor; r_2, 10^7 ohm resistor; *p*, insulating plug; *s*, spring grid connector; *a*, amplifier tube.

To make permanent records of the tracks on the lamp panel a motion picture camera has been adapted and made to function automatically. Whenever a flash occurs on the lamp panel current flows through the thyratron and through the resistance r_6, Fig. 3. The change of potential across this resistance is applied to the grid of a second thyratron which operates the mechanism of the camera. The shutter of the camera is removed so that the film is continuously exposed, but after each flash the mechanism moves the film in preparation for the next flash. A photograph of a long straight track obtained in this way on the smaller instrument is shown in Fig. 7.

In addition to the long straight tracks of single rays, multiple tracks, bent tracks, and forked tracks are also frequently seen. On the larger instrument approximately forty tracks of one type or another appear per minute. When a mass of lead or other material is placed above the bank of counters, double and triple tracks are often seen diverging from a point in the material. Occasionally such a large number of secondary rays are generated simultaneously in the vicinity of the instrument that nearly the entire lamp panel flashes at once. Such events are doubtless to be associated with the bursts of ionization studied by Hoffman and others and recently photographed in the cloud chamber.[3]

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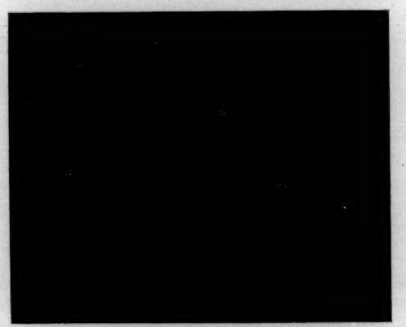
[2] J. C. Street, T. H. Johnson, JOUR. FRANK. INST., 214, 155, 1932.

Besides giving a spectacular demonstration of the cosmic rays for educational purposes the hodoscope should find applications in several types of investigations. Principal among its advantages are its continuous sensitivity and ease with which the tracks may be recorded. Although it is possible to locate the rays only within a distance of about one centimeter with the present instruments, the resolving power could be improved by diminishing the size of the counters and increasing their number. If this were carried far enough it might even be possible to distinguish between the different types of corpuscular rays. A three-dimensional hodoscope is also conceivable but would doubtless lead to some technical complications.

FIG. 7.



A straight track photographed with the 36-element hodoscope.

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[3] Blackett and Occhialini, *Proc. Roy. Soc.*, **139**, 699, 1933. Anderson, *Phys. Rev.*, **43**, 368, 1933.

In the development and construction of the hodoscope we wish to acknowledge the assistance of Mr. Lewis Fussell, Jr., and Mr. W. A. Davis. Dr. J. C. Street has made some suggestions regarding the circuits and Mr. Austin Nester has assisted in the construction and development of the counters. Materials for the Chicago instrument were supplied by the following companies: The General Electric Company, The Radio Corporation of America, The American Transformer Company, The Shallcross Manufacturing Company, and the International Resistance Company.

Healthy Tomato Seeds.—What with our present economic conditions, even the scientist and technologist must sometimes stop to wonder if many of our labor-saving devices and improvement-on-nature processes have not suffered a birth somewhat premature. Anyhow, it is an item of interest to hear that Nature on occasions emphatically reminds us that her methods, although slow, many times are the best.

Tomato seeds furnish the recent example of Nature's oft superior way of doing things. The story is told by H. L. BLOOD, of the Division of Horticultural Crops and Diseases, U. S. Department of Agriculture. Bacterial canker is a serious disease affecting tomatoes and has become quite common as well as very destructive during the past six years. Investigations showed that the seeds carried the disease and so the investigators set out to find a satisfactory disinfectant. Before proceeding with the story it should be explained that in recent years canneries and seedsmen use high speed power machinery for extracting tomato seed from ripe tomatoes. In general, the older and slower method of placing tomatoes in vats to ferment until the seeds loosened from the pulp had been discarded.

To proceed: Mr. Blood had secured a quantity of infected tomatoes and wanted the seeds for making tests of disinfectants. Not having a power extractor, the old fermentation method was used. Some of the seeds were treated with various bactericidal agents and planted along with a quantity of untreated seeds which serve as "controls." Much to his surprise the untreated seeds were practically free from disease and as good or better than the disinfected seed from the same lot. Further tests only served to establish more firmly the fact that seeds from fermented pulp remained free from bacteria while those extracted mechanically did not.

C.

SKIN FRICTION OF VARIOUS SURFACES.

BY

S. D. GEHMAN AND G. D. MALLORY,

The Goodyear Tire and Rubber Company, Akron, Ohio.

SUMMARY.

Measurements were made of the skin friction of various fabrics and surfaces due to interest in the reduction of the skin friction of Zeppelin outer cover.

A machine was designed and constructed using Couette type of flow for the purpose of making the measurements. Results obtained with the machine are in general agreement with wind tunnel results.

It was found that a smooth surface free from nap, whatever the material, approaches a limiting value for skin friction, and that as a surface becomes smoother any improvement in skin friction becomes increasingly hard to obtain.

The results are illustrated by curves.

INTRODUCTION.

The primary interest in making this study of the skin friction in air of a variety of surfaces was in order to explore the possibilities for reducing the frictional drag of lighter-than-air craft. Any reduction in power expenditure, with its consequent reduction in fuel load for long trips, would enable larger pay loads to be carried. The present outer cover of large airships like the Macon consists of singed cotton fabric which has been laced to the girders and to which has been applied successive coats of cellulose acetate dope. This shrinks the fabric taut, stiffens it, waterproofs it, and gives a hard surface which is reasonably smooth.

For the theory of skin friction and the boundary layer there is already available a recent, comprehensive bibliography (3) so that reference need be made here only to work having to do with actual measurements on surfaces.

Froude, in 1874, investigated the drag in water of a flat surface covered with fabric, sandpaper, paraffin, etc. He found that the resistance increased with the roughness of the surface and approximately with the 1.87 power of the velocity.

Zahm (10) found that smooth surfaces showed an increase of resistance according to the 1.85 power of the velocity, checking for air the exponent which Froude had found for water.

Gibbons (4) has reported wind tunnel measurements on a large variety of fabric surfaces, on varnished fabrics, and on rubber coated fabrics. The fabrics were applied to a large glass plate which was suspended in a wind tunnel. He represented his results with the equation $F = KV^n$ in which

F = frictional force in lb. per sq. ft.

V = wind velocity in miles per hour.

n has values between 1.8 and 2.1 for the various surfaces, being smaller for the smoother surfaces. He found the resistance to increase greatly with the presence of loose fibers on the surface.

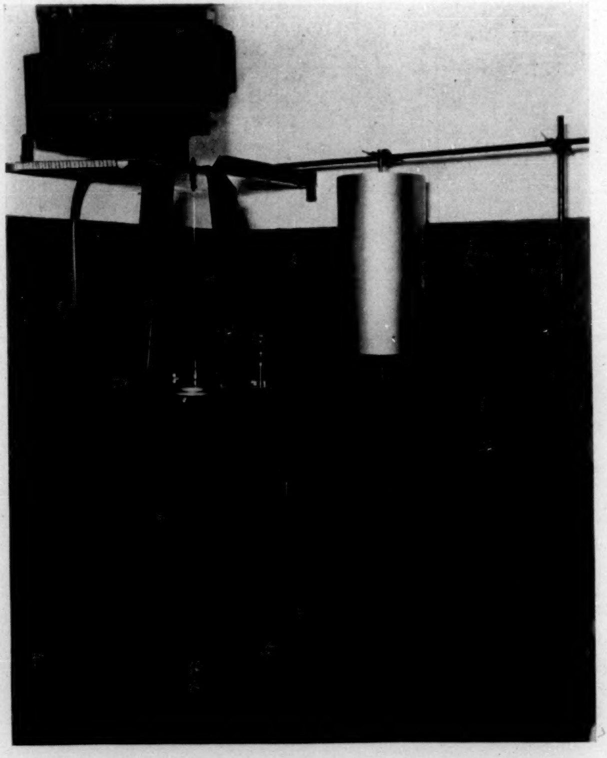
Some results of measurements at Göttingen on the skin friction of various surfaces have been published (7). The surfaces were applied to flat wooden frames which were suspended in a wind tunnel. Surfaces on which measurements are reported are cotton fabric, singed cotton fabric and doped cotton fabric. It was found that singeing cotton fabric reduced the skin friction materially and that doping produced a further marked improvement.

METHOD OF MEASUREMENT AND APPARATUS.

One of the features of the work here reported is that a laboratory instead of a wind tunnel method was employed. The method utilized the principles first introduced by Margules (6) and Couette (2) for the measurement of the viscosity of liquids, the method of rotating concentric cylinders, which has been in general use for that purpose ever since. For the theory of the method, as employed for the measurement of viscosity and a description of various researches using it, reference may be had to a recent work on viscometry (1) and to (3). The stability of the flow has been a subject of investigation (9), (8), (5).

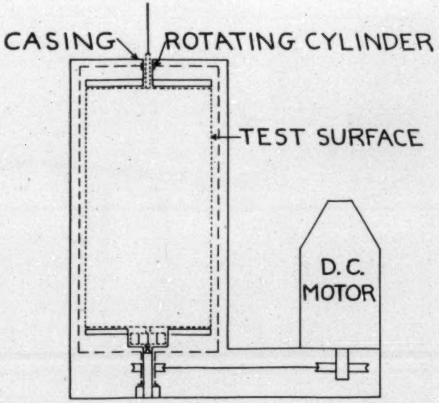
Figure 1 is a general view of the machine which was designed and constructed for the measurement of the skin friction of surfaces. It consists of a steel casing enclosing a rotating, cylindrical steel shell, $2\frac{1}{2}$ feet long and 13 inches inside diameter, driven by a variable speed motor. Figure 2 is a cross-sectional sketch of the machine. The rotating

FIG. 1.



cylinder can be driven up to 4000 R.P.M. corresponding to an inside surface speed of 154 miles per hour. Inside the rotating cylinder there is suspended, by a tempered steel torsion wire, a hollow wooden cylinder (one is shown in Fig. 1), length 24 inches, covered with the surface to be tested. The ends of the cylinder are guarded by stationary end plates as indicated in Fig. 2. Vibration in the machine was reduced by careful balancing and by bracing it securely to solid concrete walls with white pine as shown in Fig. 1.

FIG. 2.

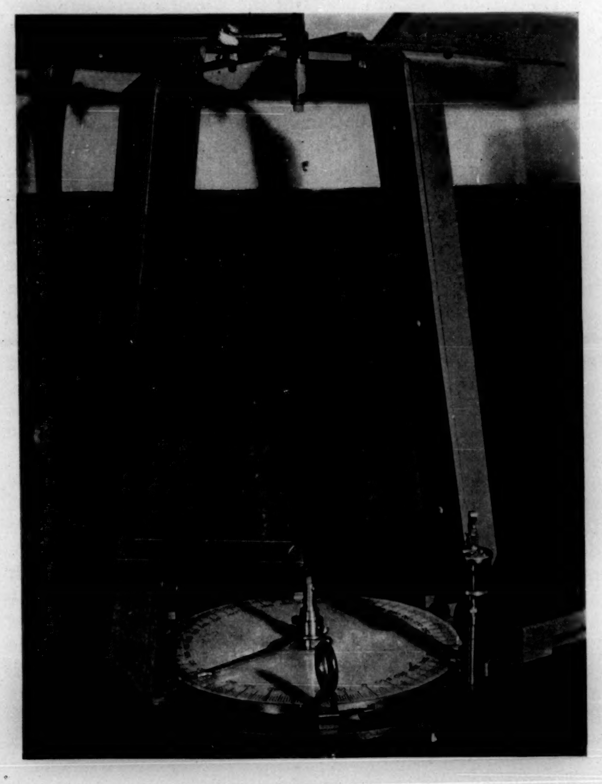


The torque on the suspended cylinder caused by the air flow set up by the rotating, outer cylinder is proportional to the surface drag and is measured by the angular twist of the suspension. The mounting of the suspension is shown in Fig. 3. The speed of the rotating cylinder was determined by timing revolutions of a countershaft with a stop watch. Cylinder revolutions and countershaft revolutions were in the ratio 30 : 1. The countershaft was supplied with a tapper which struck a bell once every revolution so that speed readings and pointer readings could be taken simultaneously by one observer.

EXPERIMENTAL PROCEDURE AND TECHNIQUE.

The internal, wooden cylinders used were made of maple in the pattern shop and turned so that there was not more than one thousandth of an inch variation from the specified diameter. The fabrics were applied to the cylinders with rubber cement and rolled down smoothly, the ends being

FIG. 3.



fastened in a neat butt splice. In the case of doped fabrics, the splice was doped and then sanded. The diameters of the covered cylinders were obtained by taping them.

The doped fabric used was prepared by stretching the fabric in a frame by means of which measured tensions could be applied in both directions. These tensions were adjusted to approximate those used in practice, the frame then clamped in position and the various coats of dope applied.

The top and bottom heads of the wooden cylinders were equipped with steel axles about six inches long. These are shown in Fig. 1 and indicated in Fig. 2. A system of steel vanes was fastened on the bottom axle by means of a set screw. These were submerged in a stationary oil bath in order to suppress oscillations. The bottom axle had a conical hole in the end which fitted on a stationary conical point in the center of the oil bath. The top axle passed through a loose fitting but accurately centered bearing in the upper guard plate. This bearing passed through a clearing hole in the center of the lid of the rotating cylinder and was clamped by a nut to the lid of the stationary casing. These arrangements are illustrated in Fig. 2. Thus, the wooden cylinder was held accurately centered, top and bottom, with reference to the rotating cylinder. The pointer and suspension wire were attached by set screws to the protruding top axle of the wooden cylinder as shown in Fig. 3. The cylinder was then lifted .015 inch by means of the nut at the top of the suspension. This removed the weight from the conical point and enabled the cylinder to oscillate freely.

The suspension wires were calibrated by using them as suspensions for a torsion pendulum. The period was found to be independent of the amplitudes used, showing that the deflection was proportional to the torque. The wires were made to order of tempered steel and gave about one-tenth of one per cent. semi-permanent set for a deflection of three hundred degrees.

RESULTS.

All but a few of the curves here given were obtained using a suspension wire of which the constant was 4.13×10^{-4} lb.-ft. torque per degree of twist. The length of the wire was 21.25 inches, its diameter .0482 inch. Where another wire was used, the results have been adjusted so that they are all expressed in terms of the angular deflection of a wire with the above constant.

Figure 4 shows the family of curves obtained by using cylinders of different diameters covered with rubberized fabric. These curves were used throughout the work in order to make small corrections to the results wherever differences in gauge of fabrics occurred in the various tests. The rubberized fabric which was used had the same skin friction as doped fabric, within the precision of the experiments. As with all the curves here given, the cylinder speed is the speed of the inside surface of the rotating cylinder.

FIG. 4.

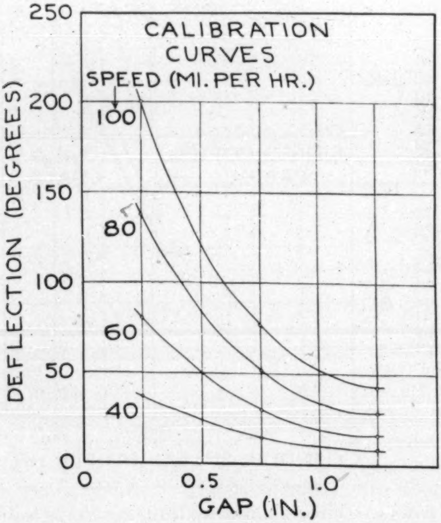


Figure 5 gives the effectiveness toward reducing skin friction of successive coats of cellulose acetate dope when applied to singed cotton fabric. The gap between cylinders was .252 inch in this test. The first two coats are practically sufficient to lay down the fibers and after that the improvement secured by additional coats is small. For singed cotton fabric the skin friction increases with the 1.88 power of the velocity; after receiving three coats of dope it increases with the 1.80 power. This is in line with the results of Gibbons (4). He found that "for very smooth surfaces, the surface friction varies with the 1.8–1.85 power of the velocity; the exponent increases with the roughness approaching 2 for fabrics with nap on the surface."

FIG. 5.

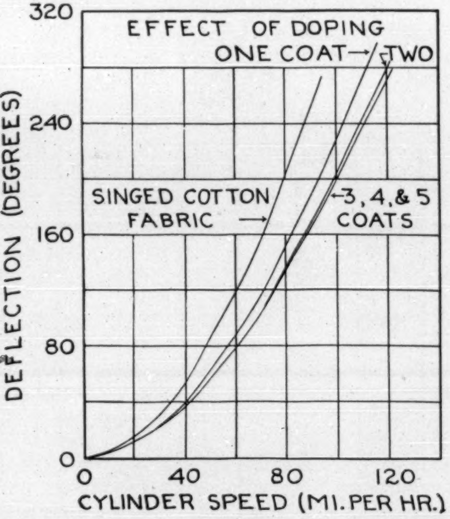


Figure 6 shows the slight improvement obtained by applying a coat of bakelite varnish to the regular outer cover prepared with two coats of clear and two coats of pigmented cellulose acetate dope. The gap between cylinders was .240 inch.

FIG. 6.

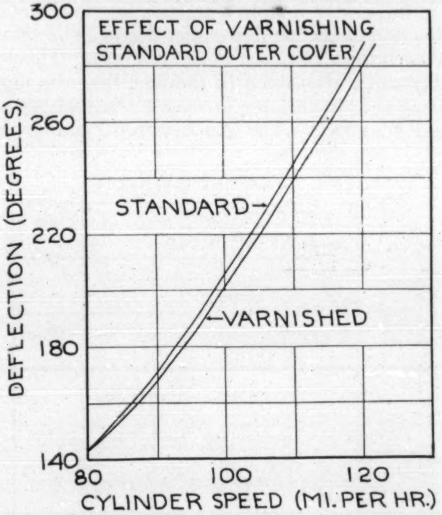
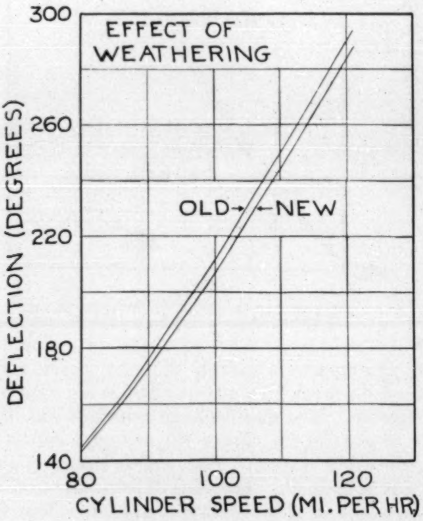


Figure 7 compares a sample of outer cover which had been in Zeppelin service for about eight years with a freshly prepared sample. The gap between cylinders was .238 inch.

In Fig. 8 are shown curves for undoped cotton, rayon, and parachute silk fabric. The gap between cylinders in this test was .250 inch. The bare fabrics are seen to have quite a variation in skin friction. But after four coats of dope were applied curves for the different fabrics practically coincide. The doped silk showed a somewhat higher friction than the other doped fabrics due to the presence of some heavy threads. The air friction for rayon was almost inappreciably changed by doping (the data indicate a slight increase of about one per cent. due to doping), showing the predominate effect of nap on the skin friction of a fabric.

The effect of nap is further illustrated by the curves in Fig. 9 for two samples of velour and for flannel. Sample A of velour had a nap which stood out radially on the cylinder whereas in the case of sample B the nap lay down tangentially in the direction of the air flow. For flannel, the skin friction increased with the 1.71 power of the velocity. This low value is probably to be attributed to the fact that the nap was so long that as the air velocity increased the nap tended to lie down more smoothly. The gap between cylinders was .432 inch.

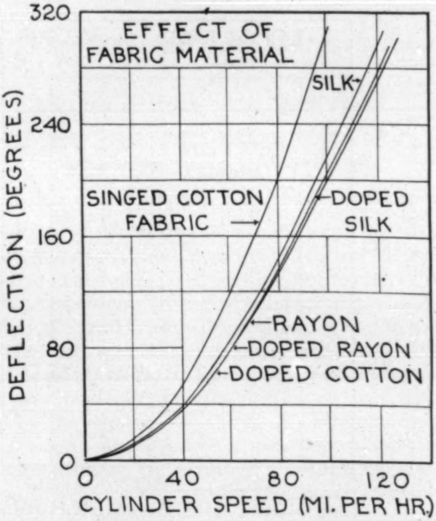
FIG. 7.



Application of wax, grease, or graphite to doped cotton fabric was found to be without appreciable effect on the skin friction. Also, various methods of doping did not produce measurable changes in the skin friction.

All the results point to the conclusion that a smooth surface free from nap, whatever the material, approaches a value for skin friction which it is very difficult to lower to any great extent.

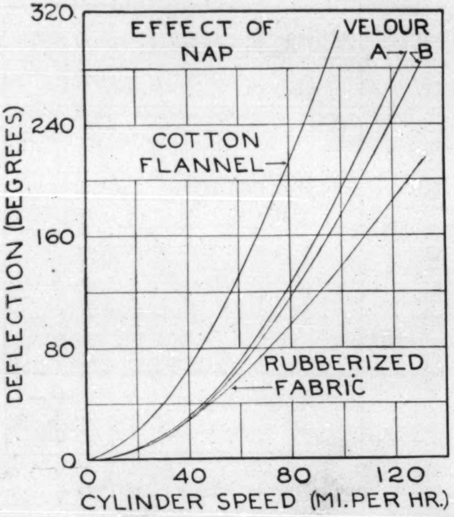
FIG. 8.



DISCUSSION OF METHOD OF MEASUREMENT.

The results obtained by this method are, in general, in line with wind tunnel results (4), (7) so that there is every reason to believe them reliable in comparing the skin friction of surfaces. The absolute values for skin friction coefficients depend upon the type of air flow, that is, upon its laminar or turbulent characteristics. The reproducibility of the results and the smoothness of the curves indicate that the machine sets up a stable and reproducible type of air flow, a condition which is, of course, necessary for the comparison of a variety of surfaces. The character of the boundary layer will vary widely over the surface of a Zeppelin so that experimental determination of the absolute skin friction coefficients for all the types of flow involved would be very difficult by any method, especially when one considers the scale effect for the surface roughness.

FIG. 9.



LITERATURE CITED.

(1) Barr, "Monograph of Viscometry," p. 212, Oxford University Press, 1931.

(2) Couette, *Ann. Chim. Phys.*, **21**, 433 (1890).

(3) Dryden, Murnaghan, and Bateman, "Hydrodynamics," Bulletin of the National Research Council No. 84, p. 253, p. 203 (1932).

(4) Gibbons, N. A. C. A. (1915).

(5) Harrison, *Trans. Cambridge Phil. Soc.*, **22**, 425 (1920).

(6) Margules, *Wien. Ber.*, (2a) **83**, 588 (1881).

(7) Prandtl, Ergebnisse der Aerodynamischen Versuchsanstalt zu Göttingen, I Lieferung, p. 120 (1923).

(8) Schlichting, *Ann. der Phys.*, **14**, 905 (1932).

(9) Taylor, *Trans. Roy. Soc. London*, A 223; 289 (1923).

(10) Zahm, *Phil. Mag.*, **8**, 58 (1904); N. A. C. A. (1922).

GAMMA RAY RADIOGRAPHIC TESTING.*

BY

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(*Concluded from page 216, August issue, 1933.*)

PHOTOGRAPHIC ACTION OF GAMMA RAYS FILMS. INTENSIFICATION.

The photographic action of gamma rays was used in the above determination (Figs. 18 and 19) to record the intensity of the emergent beam after passing through the filter. Measurements of the photographic action are practically always made with a filter of suitable absorption capacity in the path of the rays, so that the very soft rays mixed with the predominant ones shall be screened out. Not all of the rays which reach the film, however, but only a minute portion of them, are actually absorbed by the emulsion on the film. The photographically active fraction bears, however, a constant proportion to the total energy reaching the film and the total energy reaching the film is therefore measured by the degree of blackening of the film after development.

The degree of blackening can be measured quantitatively by means of the densitometer. A narrow beam of light passes through the film and onto a sensitive thermo-couple junction. The e.m.f. generated in the thermo-couple is inversely proportional to the density of the film at the point through which the beam of light passes. The degree of blackening or density of the film is given by the expression

$$D = \log_e \frac{I_0}{I}$$

or

$$D = \log_e \frac{\text{light incident on the emulsion}}{\text{light transmitted by the emulsion}},$$

where D = density, I_0 = intensity of primary beam of light, and I = intensity of the transmitted beam. A density

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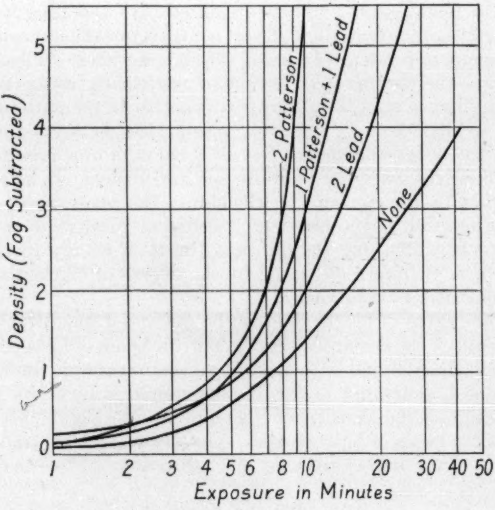
* An address presented in condensed form before the Institute on the evening of 10 November, 1932.

$D = 2.20$ (in natural logarithms) is sometimes taken as a satisfactory degree of blackening for radiographic purposes. This density refers to the increase in density due to exposure, together with that of the unexposed but developed film.

The density due to the fog (darkness of an unexposed film after development) alone amounts to about 1.15 and is then subtracted from the densities of the exposed portions for each film.

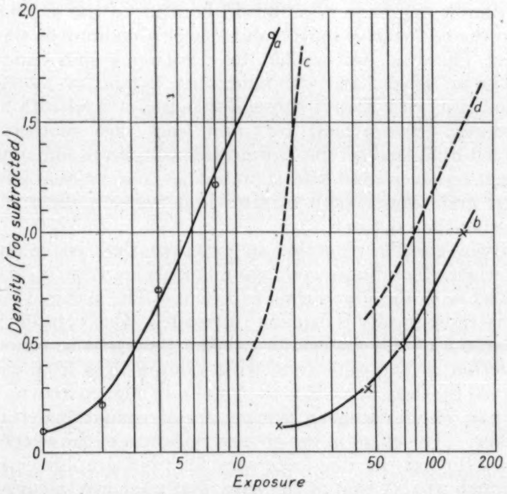
FIG. 20.



Characteristics of films with different intensifying screens for γ-rays from radium emanation filtered through one inch of iron.

Densities obtained on Eastman Super-Speed Duplitized X-ray films are plotted against exposure time in Fig. 20. Radium emanation of 250 millicurie intensity was placed at the bottom of a hollow lead cylinder of 8 inch outside diameter with a hole one inch in diameter. Across the top of the hole was laid a block of iron one inch thick and on top of this block the film in a light-tight envelope. Exposures of 1 to 32 minutes were made and the films over-developed in the following way to increase their effective speed: To one liter of standard Eastman X-ray developer[23] are added 20 milligrams of potassium iodide. The time of development was double that recommended for the film. For example, at 65° F. development may be prolonged to ten minutes, the potassium iodide preventing excessive fog.

FIG. 21.



Blackening of X-ray film by γ-rays. *a*, Agfa-spezialroentgenfilm with two intensifying screens. *b*, Agfa-spezialroentgenfilm without intensifying screens.

Developer: Rodinal 1 : 20, 18° C., 8 minutes.
c } Eastman-Superspeed { with two intensifying screens.
d } Duplitized x-ray film { without intensifying screens.

With Agfa Special X-ray films behind a filter of 30 mm. of iron, Berthold and Riehl obtained the curve *b* in Fig. 21. The results with Eastman film are shown in curve *d* for comparison, showing a greater sensitivity for the Eastman film, probably due to the over-development used. The German investigators avoided over-development because they feared that increased fog might reduce the sensitivity of the method.

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[23] "X-Rays in Industry," Eastman Kodak Co. (1929).

INTENSIFICATION OF PHOTOGRAPHIC ACTION.

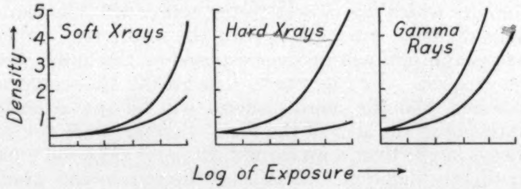
These exposure times can be reduced to a small fraction of the above values by placing the film in intimate contact with a sheet such as lead which is a copious emitter of secondary electrons as described under "Scattering" above. On the basis of Figs. 9 and 10 above, the best foils to use in this way for double emulsion films would be lead on the side farther from the radioactive source, and lead or aluminum on the near side. The lead foil should be 0.2 to 0.4 mm. thick for maximum effect, and the aluminum 2 mm. or more. An actual test with X-rays through 4 inches of steel with 2 mm. aluminum (then a film), 0.75 mm. lead (then another film), and 0.7 mm. lead on the radium side (duplicate film method) shows, however, that lead is preferable to aluminum both for speed and definition; 0.15 mm. lead appears slightly more effective than 0.3 mm.

Even greater reduction in exposure time is obtained if materials which fluoresce in gamma rays are kept in intimate contact with the film during exposure. The material used in X-ray radiography is calcium tungstate. One type of American screen of this material is called a Patterson screen. The reduction in exposure time with gamma rays from radium effected by these screens is shown also in Fig. 20 above. The German Supra Sinegran screens are of similar material but thicker. The effect of the greater thickness of the screen is to reduce further the time necessary for photographic exposure (as much as 1/35 that of the bare film) as shown in curve *b* of Fig. 19 and curve *a* of Fig. 21. For comparison, the American results are also reproduced in these figures. A comparison of the intensifying effect of Patterson screens with soft X-rays, hard X-rays, and gamma rays is given in Fig. 22.

The gradation of the Agfa films is such that with two intensifying screens a difference of density on the film is discernible to the eye (about 0.2) an intensity ratio of 1 : 1.025 is necessary. The Eastman films according to curve *c* seem to be slightly more sensitive in this respect. The German investigators do not find (as had been feared) that the

Sinegran screens diminish the sensitivity of registry by preferential action of the softer waves in the beam on the intensifying screen, as compared with lead screens. They find that while lead screens work 80 per cent. as well as *thin* calcium tungstate screens, they work only about 40 per cent. as well as thick screens of this material.

FIG. 22.



Effect of Patterson screens on film density with radiation of different wave-lengths. Upper curves density with screen, lower curves density without. Soft x-rays from molybdenum tube at 30,000 volts a.c., hard x-rays from tungsten tube at 140,000 volts d.c. filtered through 4.5 mms. copper; γ-rays from radium emanation filtered through 1″ of iron.

Although calcium tungstate is the best known intensifier of the photographic action of X-rays, it is not necessarily so for gamma rays. More than a hundred other, similar minerals were tested by the present author in 1929 in this way in an attempt to find a more strongly fluorescent substance but none of them was found equal to calcium tungstate.

EXPOSURE TIME FOR GAMMA RADIOGRAPHY.

Curve *b* of Fig. 19 gives, in milligram hours, the shortest exposures attained up to the present day. The exposure time for radiography of an object of absorption coefficient μ and thickness x, with any chosen quality of film and intensifying screens, is inversely proportional to the intensity of the radioactive source and inversely proportional to the *square* of the distance from source to film. The dependence of exposure time on intensity of source needs no discussion since it is a simple proportion. The inverse square proportion arises from the fact that the rays emanate radially from the source. If the intensity of rays falling on an area a measured at right angles to the beam and at distance d is 4, then at distance $2d$ the intensity on the same area will be 1 etc. The intensity is therefore proportional to the square of the distance between the source and the area in which measurement is made, and inversely so, in accordance with the inverse-square law. Thus in Fig. 18 if the distance d is used instead of 18 inches the time of exposure will be $(d/18)^2$ times the exposure time necessary at 18 inches. While it would thus seem most desirable to place the object as close as possible to the source this is not always feasible for two reasons. First: those parts of the film which are closest to the source will blacken more rapidly than the other parts with the result that either the centre of the film will be over exposed or the outer portions under exposed. See Fig. 23*a*.* The greater the separation of source and film the more uniform will be the intensity of radiation over the area of the film. Second: since the source is always larger than a mathematical point rays will emanate from slightly different locations on the source and when the distance from source to film is small as shown in Fig. 23*a* the rays coming from various points on the source can reach the film in line with the flaw without traversing the flaw at all, with the result that the flaw will be registered faintly if at all. If the distance between source and film is increased sharper definition is obtained as shown in Fig. 23*b*. If furthermore, the size of the source is decreased, as by the use of radium emanation adsorbed on activated carbon mentioned above, definition of the flaw is further improved as shown in Fig. 23*c*. Consequently if extremely sharp definition of minute flaws is necessary, a source as concentrated as possible and a distance between source and film as great as possible must be used. For the detection of gross flaws on the other hand, a short distance and a very short exposure time can be used. The time of exposure will therefore depend on all of these considerations.

The exposure times for various thicknesses of steel shown on semilogarithmic coördinates in Fig. 18 above, are for 100 milligrams of radium at a distance of 18 inches from the film. Eastman films and lead intensifying screens as noted were used. Figure 24 gives the times with lead sheets for distances other than 18 inches also. For metals other than steel a convenient approximation rule is the following: The exposure necessary for x inches thickness of a metal of density ρ is the same as that necessary for $\rho x/7.85$ inches of steel, where 7.85 is the density of steel. This was tested by Barrett for

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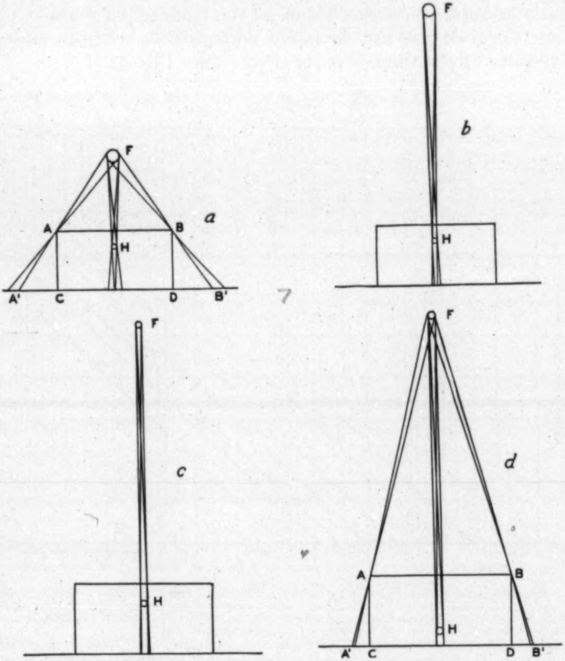
* W. L. Fink and R. S. Archer, *Trans. Amer. Soc. Steel Treat.*, October 1929), p. 535.

FIG. 23.

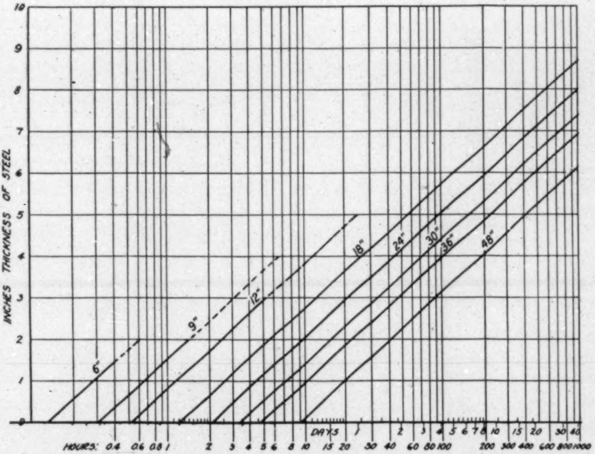


Shows effect of relative size and location of focal spot on definition. ABCD is specimen. F is focal spot. H is cavity in specimen.

aluminum ($\rho = 2.7$) by giving a section of it 5 inches thick the exposure indicated on the figure above for $\frac{2.7 \times 5}{7.85} = 1.73$ inches of steel. The resulting blackening of the film was that anticipated, within the limit of accuracy of the experiment.

In testing a group of objects of varying thicknesses and densities, it is sometimes convenient to place them at such various distances from the source that exposure is completed for all objects at the same time. When objects of irregular thickness are to be radiographed the exposure time should be calculated for the thicker parts rather than for the thinner parts because the overexposure of the thinner parts above the time necessary is not seriously detrimental, whereas underexposure of the thicker parts is so. (See Fig. 31.)

FIG. 24.



Exposure times with 125 (100 + 25) milligrams radium. Films: Eastman Diaphax, viewed singly. Intensifying screens: 3 Lead sheets. Development: Twice normal time with potassium iodide in developer. Distance radiant source to film as indicated. Note: If *two* films are exposed and viewed superimposed the times are 0.6 times those in the chart.

The exposure curves of Berthold and Riehl for steel of various thickness in Fig. 19 above show the number of millicurie hours required with a distance of 30 cm. (11.4 inches) from source to film, using Agfa Special X-ray films, for both radium and mesothorium, with narrow beam and broad beam (radiographic) conditions. The slope of these curves corresponds to their calculated absorption coefficient in iron, namely, .225 cm.$^{-1}$. The difference in exposure time for radium and for mesothorium (curves *b* and *d*) is small. The results of the American measurements are included in the figure. The longer exposure times of the latter (curve *c*) are due principally to the use of thinner and less effective intensifying screens, as pointed out previously.

Comparing exposure times of gamma rays with those for X-rays, Table 5 gives a comparison of exposure times for 100 milligrams radium or mesothorium and for X-rays from a tube operated at 200,000 volts, both sources being 50 cm. (19.7 inches) distant from the film. The exposure times are equal at thicknesses of iron of 110 mm. (4.3 inches). This comparison indicates that on this basis the exposure times *for a single object* of steel of thickness up to 110 mm. (4.3 inches) are shorter with X-rays. Above that thickness the time is shorter for gamma rays. This is a useful figure to remember.

TABLE 5.

Comparison of Exposure Times in Hours for X-Rays and for Gamma Rays (Scattered Rays Included).

Thickness of Iron, mm.	For 50 Cm. Source-to-Film Distance.				
	50.	70.	90.	110.	130.
X-Rays: * 200 K.V. 10 m.A. hours	0.003	0.04	0.7	11	195
Gamma Rays: 100 mg. mesothorium or radium hours	2.5	4.2	6.9	11	18

* Taken from R. Berthold, "Grundlagen der technischen Roentgen durchstrahlung," Leipzig, 1930, but including the more recently increased film sensitivity and intensifying action.

SENSITIVITY OF THE GAMMA RAY METHOD.

Radiographic sensitivity indicates the minuteness of the flaw, or more exactly the difference in density, within a test object, which will be revealed by the test. It is sometimes expressed as a ratio of the size of the flaw to the size of the object, both measured parallel to the path of the rays. In the absence of scattering, the ability to detect a difference in density is independent of the thickness of the section, since the flaw leads to an increase in the intensity of radiation reaching the film by a factor $e^{\mu d}$ minus $e^{\mu' d'}$ where d' is the depth of the less dense region, μ is the absorption coefficient of the adjacent homogeneous matter and μ' is the absorption coefficient of the less dense region. In practice this relation does not hold, for scattering is present and the degree of scattering is a function of the thickness of the object. The sensitivity of a radiographic method to difference in density within an object can be calculated from the sensitivity of registry of the film and from the slope of the exposure curves. For X-rays such a calculation has been made.[24]

The experimental results obtained in gamma ray radiography show a slightly greater sensitivity than the calculated results, due to the favorable distribution of the scattered rays which also act to cast a shadow of the flaw. Curves *a*, *b* and *c* in Fig. 25 show the *calculated* values of sensitivity for radium's gamma rays, mesothorium's gamma rays, and for X-rays from a 200,000 volt tube, for steel sections of various thicknesses, under broad beam (radiographic) conditions. The points lying near the curves show the observed values. These curves show the closely agreeing experimental sensitivities determined by the German investigators. The artificial flaws in these test specimens were located midway between the two surfaces of the object lying in the path of the rays. Their results for narrow beam conditions (scattering excluded) are given in curves *d*, *e* and *f*.

The effect of distance of the flaw from the film, on the sensitivity of definition of the flaw, is clearly illustrated in Figs. 23*d* and 23*c*. The closer the flaw is to the film, the sharper its definition. Thus the flaw *H* in Fig. 23*d* is sharply defined while in Fig. 23*c* there is considerable haziness of its outline. With a source of relatively large size and with a short distance between source and film, this haziness is increased as described above under "Exposure Times." For highest sensitivity as small a source as possible, for example, radium emanation adsorbed on activated carbon, and as long a distance from source to film as possible, should be used. The distance, source to film, and the size of the source were not given for the above sensitivity data. These German curves indicate a sensitivity of about 4 per cent. for radium's gamma rays in steel 100 millimeters thick; about $3\frac{1}{2}$ per cent. for mesothorium under radiographic conditions, and about 0.7 per cent. for each under narrow beam conditions. For X-rays values up to only 70 mm. of steel are given and these are respectively 0.7 and 0.15 per cent., that is a very much greater sensitivity for X-ray radiography for sections of this thickness and below.

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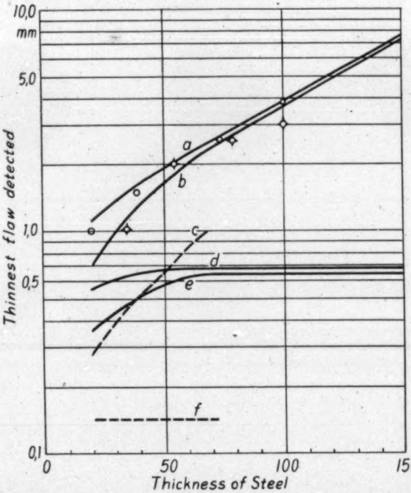
[24] R. Berthold, "Grundlagen der technischen Roentgendurchstrahlung," Leipzig, 1931.

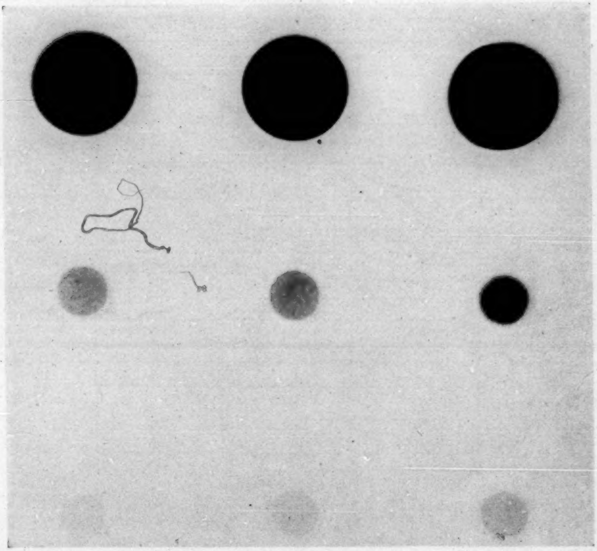
FIG. 25.



Sensitivity of flaw detection. *a*, radium, broad beam. *b*, mesothorium, broad beam. *c*, x-rays 200 k.v., broad beam. *d*, radium, narrow beam. *e*, mesothorium, narrow beam. *f*, x-rays 200 k.v., narrow beam.

The American investigations of sensitivity were made by milling slots of various depths and widths, as shown in Fig. 17, in a steel plate about 12 inches square. This plate was placed *next to the source* and other plates to a total thickness of 4 inches were packed between it and the film. The distance from source to film was 18 inches, the source was a cylindrical capsule approximately 1/4 in. × 1/2 in. long. The narrowest and shallowest slot, No. 3, was 1 mm. wide by 2 mm. deep and is clearly defined on the radiograph at "3," in Fig. 13, indicating a sensitivity of about 2 per cent. under the unfavorable condition of the flaw being as far as possible from the film. The results of a similar experiment is shown in Fig. 26. Holes of various depth and diameter were drilled in a steel plate of thickness $1\frac{1}{2}$ inches shown in Fig. 17. Again the holes were as far as possible from the film, giving the

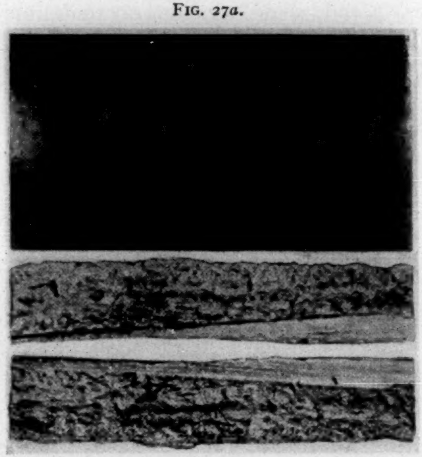
FIG. 26.



Radiograph of drilled steel plate shown in Fig. 17, with total thickness $1\frac{1}{2}$ in.; distance, source to film 18 in.; exposure 175 milligram hours using 3 lead screens and 2 films; Dimensions of holes: top row, 1 in. diameter, $1\frac{1}{2}$ in., 1 in. and 3/4 in. deep; middle row, 1/2 in. diameter, 5/8 in., 1/2 in., 5/8 in. deep; bottom row, 1/2 in. diameter, 1/16 in., 1/8 in., 3/16 in. deep.

least favorable condition for detection. The hole 1/16 in. deep is clearly registered at the left in the lower row indicating a sensitivity of 4 per cent., without reaching the limit of sensitivity. The sensitivity indicated in these experiments is considerably greater than that found by the German investigators.

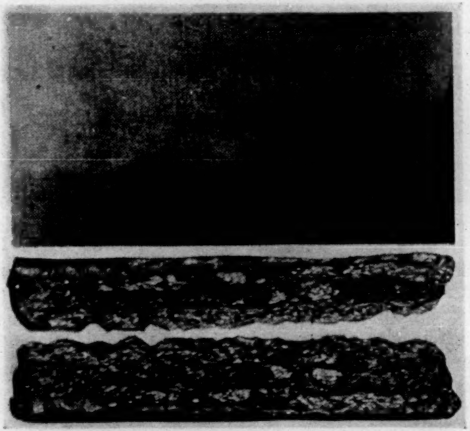
FIG. 27*a*.



Gamma-ray radiograph of a sound weld. The fracture of the weld is shown below.

2

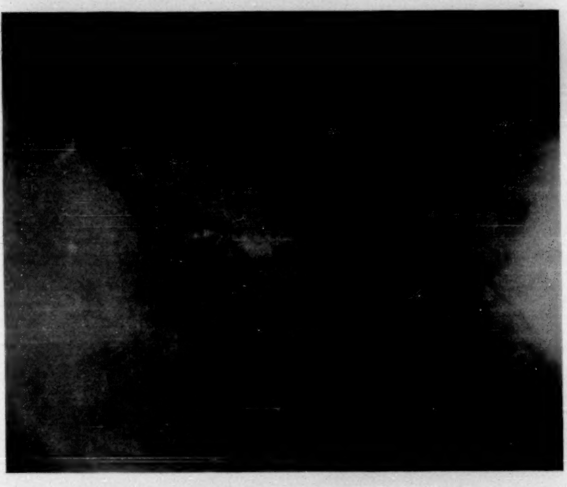
FIG. 27*b*.



Gamma-ray radiograph of a defective weld showing lack of fusion. The fracture of the weld is shown below.

Figures 27*a* and *b* show * a gamma ray radiograph of a food, and of a defective arc weld in 1/2 inch steel plate together with the fractured section made after radiography. The distance source to film was 32 inches, the source being a needle about 1/8 in. thick by 1 in. long. Apparently the gamma ray method is adequately sensitive for testing welds, although it is certainly not as sensitive as are X-rays, and the latter are preferable for this purpose where they can be used.

FIG. 28.



Internal cracks in a steel casting.

Figure 28 shows a group of shrinkage cracks in the interior of a cast steel section 6 to 7 inches thick at one side of the film and 5 inches thick at the other. The cracks are clearly revealed. The size of flaws which need detection in industrial practice varies greatly, of course, with the nature and size of the object.

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* Doan, l. c.

The half-tone reproduction of radiographic films is always a relatively unsatisfactory affair. Differences in density which are clear and unambiguous on the film may disappear entirely in the process of reproduction for printing. This is true of X-ray radiography as well as gamma ray radiography.

The most satisfactory method of viewing films is before the viewing cabinet such as is used in hospital work. Additional certainty in interpreting a faint marking on a film is obtained by exposing *two* films together behind each object which is examined, with suitable intensification screens on both sides of each film. There is less doubt whether a faint marking may be due to a defect in the film or in its development. The exposure time to produce a visible blackening on two films, if viewed superimposed, is shorter than that for one film and the saving in time is usually worth the cost of the extra film and its development.

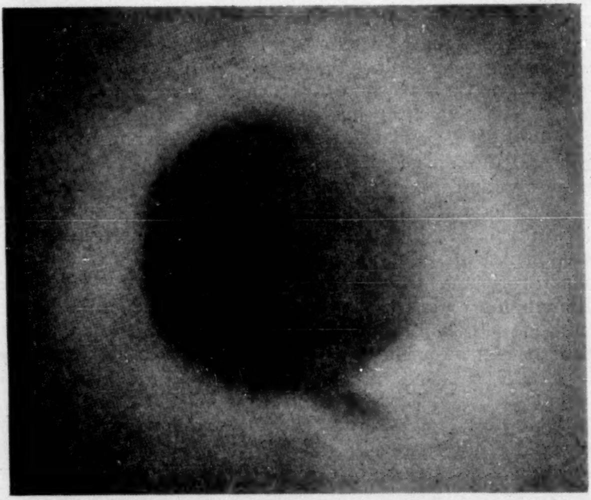
Another method of viewing a film is to lay it upon a sheet of white paper. The light passes through the film once on its downward course and again after it is reflected from the paper to the eye, thus accentuating the contrast. Less dense films than used in the viewing cabinet are best suited for this method, and the double film is of relatively little advantage, under these conditions, in detecting differences in density.

PRACTICAL PROCEDURE IN ROUTINE TESTING.

Under any given set of conditions, that is, with a source of given size and intensity, and with certain films and intensifying screens, one of the first considerations in planning an exposure is the size of the smallest flaw which it is desired to detect. If minute flaws such as those in welds are to be detected, the distance from source to film should be as great as permissible and the source as small in size as possible. Since the time of exposure increases as the square of this distance the choice of distance will be influenced by that consideration. If on the other hand relatively gross flaws, as gas cavities or gross porosity in a casting weighing many tons, are sought, this distance may be made very short. For instance a hole $1\frac{1}{2}$ in. deep and 3 in. in diameter in a synthetic block of steel 10 inches thick will be adequately revealed as in Fig. 29 when a distance, source to film, of 12 inches and a relatively large source of rays such as 6 bulbs of emanation are used. Once the distance from source to film has been chosen, and the size of the source, as well as the quality of films and screens, the time of exposure is fixed by the graphs given above.

In all cases it will be most expedient to surround as completely as possible the source with test objects and thus to use as nearly as possible all of the broadcasted rays emerging from it. A great circle of small objects (welds) at distances from 31 to 36 inches from the source is shown in Fig. 30. Obviously many such great circles could be exposed at the same

FIG. 29.

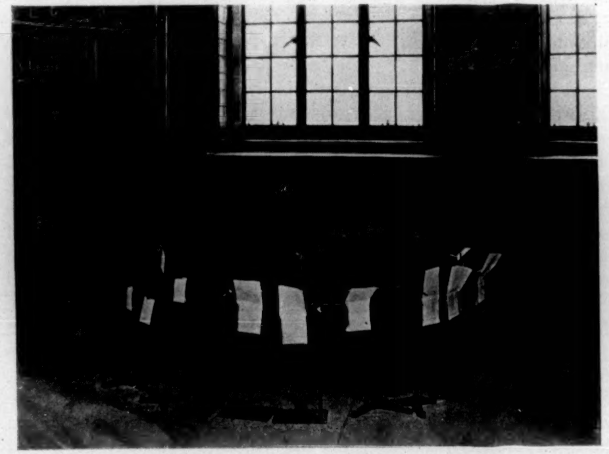


Distance, source to film	12¼ inches
Intensifying screen	None
Time of exposure	10¾ hours
Mean strength of emanation	2100 m.c. in six bulbs

Results: Underexposed. Another film taken simultaneously with two Patterson screens, had nearly correct density for viewing by reflected light when backed by white paper; by mistake the poorer of the two was sent for reproduction. On both, the hole 3 inches diameter and 1½ inches deep are shown clearly and the 1-inch hole 1½ inches deep barely seen; on the better film both slots are faintly recorded. The ½-inch holes do not appear. A single bulb with a correspondingly longer time would have considerably improved the definition in this and several other films.

time with very sharp definition and with correspondingly short time of exposure, when calculated per object exposed. A small group of larger objects is shown in Fig. 17 above. Usually it will be worth while to construct a spatial frame on which a large number of objects can be exposed simultaneously. In order to utilize the time to best advantage several such frames can be constructed and while one group of objects is being exposed, the second frame can be supplied with test objects. In this way the radioactive source may be transferred by an attendant (or by the loader himself) as soon as exposure of the first frame is completed. In routine examination of objects the source could thus be usefully employed nearly 24 hours a day, the films (and objects) being numbered and allowed to accumulate during the night for development next day, or vice versa.

FIG. 30.



Great circle of test objects about the source in γ-ray testing.

No exposure of the operator to personal injury is necessary in the conduct of the operation. When removing the source from one frame to the next, forceps or tongs a foot or two long, together with the length of his extended arm, will give adequate protection for the short time involved in transfer. At other times the best precaution is to stay away from it as far as possible and thus depend on the action of the inverse square law for protection. When the source is to be stored where persons pass near it, a housing of lead as thick as 6 inches is adequate protection. For transportation a thinner lead wall may be used and a suitable distance maintained.

To test the degree of personal exposure, it is useful for the operator to carry a small bit of unexposed film in a light tight envelope in his pocket. Some operators feel that if the film does not blacken in two weeks, their exposure has been negligible.[25]

Where objects of greatly dissimilar sections are to be exposed the thinner portions may be shaded from over-exposure by applying to them uniformly thick layers of a plaster made of lead chips or iron filings in a binding matrix, as is done in X-ray radiography. It is of practical importance in connection with the testing of objects of varying thickness to note that gamma rays permit quite a wide latitude of thickness in the same object, without requiring these paste screens to avoid over-exposure of the thinner parts and without requiring two exposures to be made, one for the thicker parts of an object and another for the thinner parts, as is frequently done in X-ray radiography. Figure 31*a* shows the X-ray radiograph of a sand casting about 1/4 inch thick, with reënforcing ribs $1\frac{1}{4}$ inches thick. The exposure time was chosen for the thin parts of the object. Figure 31*b* shows the γ-ray radiograph of the same object. It may be noted that whereas the thicker (ribbed) parts are under-exposed in the X-ray radiograph, neither the thick nor the thin parts are so in the gamma ray one. Nevertheless the sand inclusions are clearly shown in both thick and thin sections of the latter, while they are not visible in the thick parts of the former radiograph. The greater penetration of gamma rays thus permits greater latitude of thickness in the object without requiring separate exposures for each part. The contrast between flaw and homogeneous metal is sharper with X-rays, but every defect visible in the X-ray radiograph is also visible, although with diminished contrast in the gamma ray one. Figure 32 shows [2] how simply the walls of a cylindrical vessel or pipe may be examined by placing the radiant source at the axis of the cylinder and girdling the outside of the cylinder with several belts of films, all of which may be exposed at one time.

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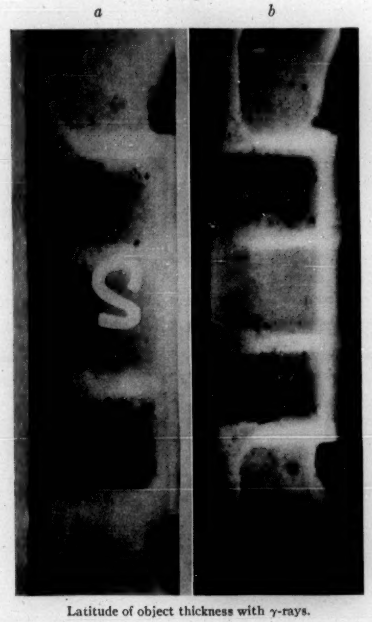
[25] See recommendations of Hospitals, etc. and of National Physical Laboratory, England (1929), etc.

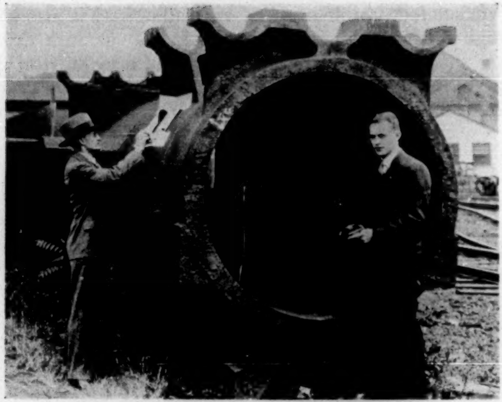
FIG. 31.



Latitude of object thickness with γ-rays.

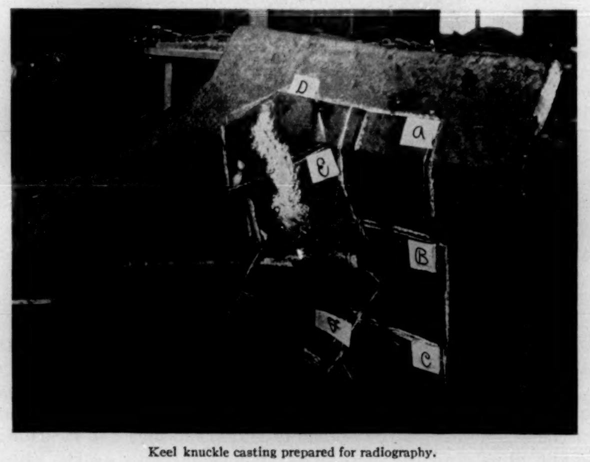
Figure 33 illustrates [4] the practical application of gamma ray radiography in testing the keel knuckle casting of one of the U. S. Navy's 10,000 ton cruisers, showing the locations of the films, and the lead letters whose shadows on the films

FIG. 32.



Testing cylindrical vessels.

FIG. 33.



Keel knuckle casting prepared for radiography.

serve for identification. Figure 28 above shows some of the cracks found.

COST OF RADIOGRAPHY BY GAMMA RAYS.

The cost of radiation per specimen tested will depend in large degree, under any given set of conditions (such as size of source, kinds of film and screens, etc.), upon the distance between source and film (that is, on the size of the flaws to be detected), upon the degree to which the source may be entirely surrounded by test objects, and upon the continuity with which the source is employed. To the cost for radiation must be added the cost of labor in assembling the objects, the cost of films and development and of time required for examination and interpretation of the films.

It will be simplest, perhaps, to calculate the cost of the operation first on the assumption that one gram of radium is to be bought outright. Furthermore, for purposes of simplicity in calculation, let us assume that the radium is used 24 hours a day for 250 days per year, i.e., 6,000 hours per year. Obviously in certain cases it will be used much less than this in the course of a year, and obviously also it may be used the full 365 days without additional cost for radiant energy delivered. At an initial cost of $70,000 per gram the figures below indicate a cost of $10,500 per year, exclusive of films and chemicals, or about $1.67 per hour.

TESTING BY GAMMA RAYS.

Operation of a One Gram Plant.

Interest on Investment at 6%	$ 4,200.00
Insurance on Radium	2,100.00
Salary of Superintendent	3,000.00
Salary of Laborer	1,200.00
	$10,500.00

$$\frac{\$10{,}500}{250 \text{ days}} = \$40.20 \text{ per day or } \$1.67 \text{ per hour}$$

If only half a gram is purchased, the cost would be reduced by $3,150 to $7,350.

If minute flaws are to be detected a distance of 18 inches source to film might be desirable. The next question is "How many objects can be grouped about the source at this distance at one time?" Here enters a "shape factor" which will determine how closely the objects may be packed on the surface of the imaginary sphere 36 inches in diameter about the radium. Assuming a shape factor of unity, that is, that the entire surface may be filled with test objects, the volume of steel one inch thick that could be tested at one time would be the volume of a sphere 36 inches in diameter minus the volume of the inner space 34 inches in diameter or 3,830 cubic inches of steel. The time of exposure (from Fig. 18 above) using the cheaper although less effective lead screens instead of those in Fig. 19 is .15 hours (160 tests per 24 hours) giving a cost of testing per pound of steel or iron tested of .023 cents per pound. The cost of films and chemicals at 1/2 cent per square inch of film would be an entirely simple calculation and the same as for X-rays, and for this thin section of metal 1.8 cents per pound.

In a similar manner the cost for material 3 inches thick comes out .061 cents per pound and additional 1 cent per pound for films and chemicals. For material 6 inches in thickness, the cost of exposure would be 0.26 cents per pound and an additional 0.5 cents per pound for films and chemicals. The exposure cost increases and the film cost decreases per pound tested as the thickness of the material tested increases.

Obviously these exposure costs (not the film costs) represent minima and should be multiplied by a shape factor perhaps as great as 10 to 1, but it is necessary to assume some basis for calculation and it seems most convenient to assume an ideal case and then modify it for each individual departure therefrom.

The above figures are for the thin (Patterson) screens. If the thicker German Supra Sinegran screens are used, the German investigators report reduction of exposure time to 1/10 that with the thinner American screens. The figure obtained by the American investigators with thicker screens is 1/7. This results in further lowering of the cost of the operation below that calculated above. But it is evident that the film costs, which are the same in X-ray and in gamma ray testing, constitute the larger part of the total cost in these examples. Costs of this magnitude for testing would constitute a very slight increase in the basic production costs of some metal objects. For some objects, where the risk involved in defects is small, this increase in cost for testing would not be justified, while for others such as high pressure valves etc. it would enhance their value enormously.

The German investigators have calculated costs on a slightly different basis. Their calculations on four different bases follow. They have divided total cost into two parts:

1. The amortization of investment, in the case of radioactive substances of long life (radium, mesothorium), or the cost of purchase of a substance of short life (emanation); or the rental price of a substance of long life.

2. The operating costs. (Insurance, labor, photographic material, etc.)

The expense in each possible case is computed as follows:

(*a*) Expense for the permanently acquired radium salts: Assume an investment of 10,000 RM. ($250) in radium. At present prices, this would buy 37 mg. Because of the rapid decline in price of radium in the last few years (accompanying the development of the mines in the Upper Katanga, a region of the Belgian Congo), these investigators believe that the half-life period of 1645 years should be neglected in amortizing the investment, and instead of 1645 years a period of 20 years taken for amortization. In view of the small quantity of radium present in the earth's crust, and the probable early exhaustion of the rich African deposits as developed below, this assumption seems unwarranted to the present author. However, on this basis, they set aside 950 RM. per year for amortization. For insurance of radium (3 to 4 per cent. of the investment) 350 RM. per year. They assume the source will be used only 1,500 hours per year which would seem to be a rather low estimate on any efficient production basis. For preparation of films, grouping of objects, development and interpretation of films 20 per cent. of the total exposure time or 300 hours per year are estimated. Assuming two helpers to do the work of preparation and development of films this item for services is estimated at 750 RM. The sum of these costs is 2,050 RM. or about $500 per year, or 1.37 RM. (about 37 cents) per hour of use. If 1,000 mg. of radium are purchased and if it is used 6,000 hours per year as in the American estimate (250 days, 24 hours a day) the German costs for radiation and services would be $9,522 per year, which compares closely with $10,500 the American estimate. To each of these must be added the cost of film and of chemicals for developing them. The first German example ($500 per year) is that of a small plant used for occasional testing. The American example is that of a powerful plant used in a routine manner.*

(*b*) For a 10,000 RM. investment in mesothorium (59 mg. at 170 RM. per mg.) consideration of the half-life period of 26 years must include the *increase* in intensity during the first 3 years due to formation of radiothorium (see Fig. 7 above). Because of this rise the firm supplying the mesothorium will exchange it without cost after 3 years for a fresh sample of mesothorium, covering their sacrifice of mesothorium by the gain in the more valuable radiothorium. For this reason the same amortization rate is chosen as that used for radium, namely 20 years, 950 RM. per year. The insurance, labor and film costs are considered the same as for radium above.

(*c*) Expense with use of Radium Emanation: The short-lived (half-life period 3.85 days as in Fig. 7) radium emanation may be bought for 4 RM. per mg. or for 30 mg. 120 RM. The average intensity of this source over a period of 4 days or 60 hours corresponds to 25 mg. of radium. The cost per hour is 2 RM. per hour. Insurance cost is zero. Labor for 20 per cent. of the exposure time of 60 hours—15 hours or 30 RM., giving a total of 150 marks for 60 hours or 2.5 RM. per hour. Cost of photographic materials as above is to be added.

(*d*) Rental of mesothorium: 30 mg. of mesothorium can be rented for one month for 150 RM. A rented source will always be used more intensively than an owned source, but less intensively than the short-lived emanation. If used 250 hours in one month, the labor time being again 20 per cent. of exposure time or 50 hours and costing 125 RM., the cost per hour is 1.10 RM. Films and chemicals additional as above.

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* If the small German plant .37 mg. were used 6,000 hours per year, as in the American estimate, the cost for radiation would not rise at all but only that for labor, and the total yearly cost (except films and development) would be 4,300 RM. (or $1,075) of which 3,000 RM. is for labor (1,200 hours). This rate would correspond to $\frac{4{,}300 \text{ RM.}}{6{,}000 \text{ hours}}$ (about 20 cents) per hour.

For film and development including chemicals 0.30 RM. per 100 cm.^{2} of film area is added.

Berthold and Riehl then proceed to calculate the cost *per exposure* from the exposure times for given thicknesses of steel and from the above costs per hour, *assuming that one exposure is made at a time.* The costs per exposure are shown, and compared with cost of X-ray exposures* in Fig. 31. The curves are for a distance of 50 cm. (23 in.) from source to film as is used in X-ray radiography. They show emanation to be the most expensive per exposure, but point out that this is not always the case because:

1. The emanation can be concentrated into a smaller volume than can the solid sources and therefore will give a sharp image of a flaw at a shorter distance from the film, thus reducing the exposure time as the square of the reduced distance, and lowering the cost of exposure.
2. The danger of loss or injury to the source is much less than with the solid sources.
3. Under certain conditions the price of emanation will be reduced by the supply firm.

To the costs given in Fig. 34 are to be added .30 RM. for each 100 cm.^{2} of film surface and for chemicals for development. The curves show the rapid decline of economy in using X-ray methods above 100 mm. thickness of steel. The comparative costs are practically independent of the assumptions made in the individual calculations above. They also show the cost advantage of using mesothorium instead of radium.

The fallacy underlying the entire German basis of cost estimation clearly lies in the assumption of exposing one object at a time to the broadcast rays of radium for no other reason than that the X-rays method is limited to this procedure.

If a minimum of four objects is exposed at one time instead of one object at a time, German cost for radiography of steel objects would be, excluding film and development costs, for objects about 1 inch thick .50 RM. per exposure instead of 2.0 RM. (X-rays 0.3 RM.), for objects 2 inches thick 1.10 RM. instead of 4.50 RM. (X-rays 0.65 RM.), for objects 3 inches thick 2.20 RM. instead of 9.0 RM. (X-rays 1.5 RM.) and for objects 4 inches thick 2.5 RM. instead of 18.0 RM. (X-rays 3.5 RM.). To each of these the cost of film and chemicals must be added.

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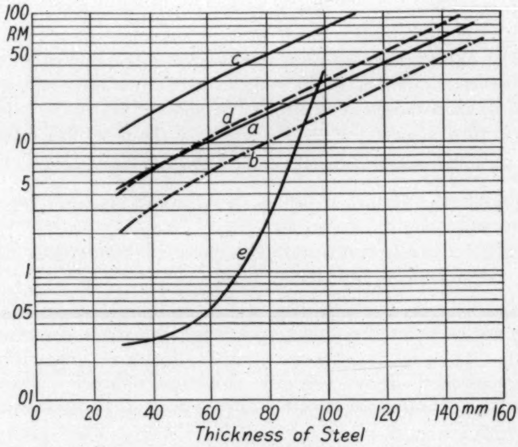
* For an X-ray equipment costing 10,000 RM., 200,000 volts 10 m.a. amortization in 10 years at 7 per cent. Used 800 hours per year with two helpers. See R. Berthold, "Grundlagen der technischen Roentgen durchstrahlung." Leipzig, 1930.

FIG. 34.



The basic costs for one exposure with radioactive materials.
a, radium } permanently owned. *b*, mesothorium } permanently owned.
c, radium emanation, owned.
d, mesothorium, rented.
e, x-rays for comparison.

At the distance source-to-film, 50 cm. (23 inches) used in this comparison the surface of a sphere 46 inches in diameter could be occupied by test objects at one exposure. For smaller objects 6 or even double or treble this number could be exposed at one time instead of one, as assumed by the German investigators, thereby cutting the costs (less films) per object tested proportionately. With a distance of 23 inches and in the ideal case taken for calculation in the American example, that is, with the entire surface of a sphere

46 inches in diameter occupied by test objects, no time lost in transfer of the source from one group to the next, and using mesothorium with the exposure times found by the Germans, that is for 1 inch of steel .45 milligram hours, or with 1,000 mg. = .045 hour (2.7 minutes), the weight of steel tested in this time would be 1,617 lb. The cost of testing this weight would be 2 RM. or .0012 RM. = .0003 cent per pound. Obviously with so short an exposure time the loss in time in shifting the source would be at least as much as the time required for one exposure, i.e., 2.7 minutes and the cost above should be doubled, giving .0006 cents. But if it is also multiplied by 10 as a shape factor, giving .006 cents, it is still quite low as compared to X-ray costs in which only one object is exposed at a time. *If 7 objects one inch thick are exposed at one time at 50 cm. distance, the cost of testing steel one inch thick with gamma rays is brought down to equal that of X-rays if one object at a time were exposed.*

In summary of the cost question, it may be stated that if only one exposure is to be made at a time it is cheaper to use X-rays when the thickness of steel is below 4 inches, but that if a large number of objects are exposed at one time the gamma ray method may be cheaper not only for 4 inch sections but also for very much thinner sections, depending upon the number of objects exposed at one time. Especially if the testing schedule is carried out in a routine manner as in commercial production programs, does the gamma ray method offer advantages in cost. The cost of films and development is the same per object tested in both methods.

SOURCE OF SUPPLY OF RADIOACTIVE MATERIALS.

Occurrence of Radium.[26]

"Unlike most other elements, it is not possible for radium to occur naturally in a pure or concentrated form. This is because radium is one of a series of unstable elements which, by a constant, spontaneous, atomic disintegration, change from one element to the next in the series. Uranium is the 'grandparent' of radium. The rates at which radium atoms are 'born' and 'die' are so related that only one part of radium can exist in equilibrium with three million parts of uranium. Consequently radium is only found associated with uranium minerals, and the ratio of radium to uranium is never more than one to three million. Since uranium is a rather rare element, the scarcity of radium is almost beyond comprehension. Nevertheless minute traces of radium can be detected in nearly all rocks."

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[26] Bureau of Mines Report, R.I. 3057, Dec. 1930: "Processes for Extracting Radium from Carnotite."

"Because of the small quantities of radium present in its ores, the economical extraction of radium presents problems substantially different from those encountered in other fields of metallurgy. It is not unusual to treat 200 tons of ore to obtain 1 gram of radium, a yield of only one part in a hundred and eighty million. The high unit value of the material introduces a factor calling for an extraordinary amount of analytical and other technical control. Such control is made possible by the fact that infinitesimal quantities of radium (one-millionth of one-millionth of a gram) can be detected and measured with considerable accuracy in an electroscope."

Market Conditions.[26]

"The carnotite ores of Colorado and Utah were the chief source of radium for many years.

"In the fall of 1922 news of the very rich deposits of radium ore discovered in the Belgian Congo caused almost complete cessation of domestic production. The Congo ore contains pitchblende and a number of alteration products, including the new minerals bequerelite, curite, kasolite, stasite, and dewindite. Reports indicate that a considerable amount of ore containing over 50 per cent. uranium oxide has been produced. It seemed certain that radium could be extracted from the Congo ore at a much lower cost than from the relatively low-grade carnotite; and in order to preserve their elaborate marketing organizations, the larger American producers made agreements with the Belgian syndicate to market the foreign product in this country. The retail price of radium has been held at $70 per milligram, but large orders are filled as low as $50. Extraction of radium from carnotite by the usual methods does not appear to be profitable at that price. With one exception, all American firms ceased production after their accumulated stocks of ore had been treated. The United States Radium Co., which continued to treat carnotite for several years, finally shut down its plant.

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[26] L. c.

"Probably a large profit is derivable from the treatment of Congo ore, but it is not likely that the Belgium syndicate will meet sufficient competition to cause any reduction in the present quotations. It is not known how long the high-grade ore will last, but when it is exhausted the price of radium may be expected to advance."

"Practically all the carnotite deposits have passed from the hands of radium producers and are now owned by corporations interested in them as a source of vanadium."

"Ores from Belgian Congo are 20 times as rich in radium as the average carnotite ores. Since 1923 when radium from these Congo ores came on the market at $70 a milligram, domestic production of radium has ceased. All authorities agree that radium can be recovered from Congo ores at a much lower cost than from carnotite."

Experts have estimated that the cost of production of radium from the Congo ores is probably between $5 and $10 per milligram.[27]

"By far the most important feature[28] in 1931 in connection with radium and its associated metals is the development of the deposits in the Great Bear Lake region of the Northwest Territories, Canada. The original discovery was made in May 1930, but it was not until the summer of 1931 that active work could be gotten under way. The development of these deposits is greatly hampered by their remoteness from transportation and the heavy winters, so it is too early to predict their commercial importance, but the extreme richness of the veins indicates the possibility that there is now available on the American continent a source of radium that can compete, both in quantity and in cost of production, with the Congo, which has for several years produced the bulk of the output. The magazine "Time (9 Jan. 1933, p. 35) reports:

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[27] Bureau of Mines Publ. No. R.I. 3057, Dec. 1930; I.C. No. 6312, Aug. 1930; "Mineral Resources," Dec. 17, 1929, Part 1, pp. 135–140. *Jour. Ind. and Eng. Chem.*, 1 July, 1929, p. 615; 1 Nov., 1931, p. 1187. *Jour. Amer. Medical Assn.*, Vol. 96, No. 2, Jan. 10, 1931, p. 125.

[28] "Mineral Industry, 1931," pp. 488–490. McGraw-Hill Book Co.

Canada's pitchblende deposits at Great Bear Lake are about ready to produce 1 gm. of radium for 10 tons of ore in six weeks and a score of refining steps (against the Belgian Congo method of 3 mo. and 40 steps). Some 4,000 gm. of radium concentrates are ready for the refinery at Port Hope, Ontario. The Canadian process promises much cheap radium for the world, new wealth for Canada.

"*United States.*—For several years the operation of radium deposits in the United States has been prevented by the low cost of production from the much richer ores of the Belgian Congo, and the only demand has been for small amounts of rich carnotite ore for making radioactive drinking water, supplied from sources in Colorado and Utah. The large amount of publicity given to a recent death, reported to have been due to drinking radioactive water, will probably curtail somewhat even this meager demand.

Imports for Consumption of Uranium and Radium Salts.

	1929.		1930.		1931.	
	Quantity.	Value.	Quantity.	Value.	Quantity.	Value.
Uranium oxide and salts of (pounds).........	272,913	$344,548	231,194	$306,566	....	....
Radium salts (grams) (*a*).................	10.69	579,085	16.86	924,852	13.42	$731,204
Radioactive substitutes (*b*)................	(*c*)	183	(*c*)	971	....	....

(*a*) The items were given as: 1929, 165 grains; 1930, 260 grains; 1931, 207 grains.
(*b*) Previously reported as radioactive substances.
(*c*) Weight not reported.

"*Australia.*—The Australian Radium Corp. resumed operations at Mount Paynter, South Australia, with the expectation of submitting a test shipment of ore to the treatment plant at Dry Creek, near Adelaide. The radium-bearing minerals are autunite and torberite.

"*Belgian Congo.*—The annual report of the Societe Generale gives the 1930 output of radium as 60 grams, the same as in 1929. The output since the beginning of operations is as follows:

	Grams.		Grams.
1923	20	1927	26
1924	22	1928	42
1925	20	1929	60
1926	20	1930	60

Total to end of 1930
270 grams

"The exports of uranium ore from the Congo in 1931 were 382 metric tons.

"*Canada.*—In May, 1930 extensive deposits of pitchblende, associated with silver and other metals, were discovered at Echo Bay, on the eastern shore of Great Bear Lake, Northern Territories, and small shipments of ore were made for experimental purposes. Active prospecting and development work was started as soon as transportation was open in the spring of 1931, and three veins have been traced over a total distance of more than a mile, with a vein thickness of from one to six inches of pitchblende. The pitchblende veins carry some silver, and parallel to them over much of the area are rich silver veins, varying from a few inches to several feet in width, and carrying up to 9,000 oz. of silver, along with cobalt, bismuth and copper. Vein samples from the pitchblende carried from 30 to 62 per cent. uranium oxide, equivalent to one gram of radium in from 6 to 13 tons of ore.

"During 1931 about 20 tons of high-grade pitchblende was mined and shipped to the Government laboratories at Ottawa for experimental purposes. The Eldorado Gold Mines, the original discoverers and the chief developers of the deposits, have announced that negotiations are proceeding for building a plant for the treatment of the ore and the recovery of the radium.

"In addition to the Great Bear Lake operations, the International Radium and Resources, Ltd. (formerly the Ontario Radium Corp.) continued to develop, its uraninite deposit near Wilberforce, Haliburton County, Ont. Underground work disclosed several veins carrying disseminated uraninite, and late in the year a mill was erected.

"The Great Bear Lake deposits have been extensively described in the literature, and the more important references are the following:

McDonald, Roderick C.—Surveys at Great Bear Lake, 1931. Trans. Can. Min. and Met. Soc., Bull. 240, April, 1932, pp. 209–223.

Reid, J. A.—The minerals of Great Bear Lake, Note on the Geology and Mineralization of the Echo Bay Region, Great Bear Lake. *Can. Min. Jour.*, 53, 61–66 (1932).

Spence, Hugh S.—Radium-bearing minerals from Great Bear Lake, Northwest Territories. Memorandum Series No. 48, March, 1931. 4 pp. Republished in *Can. Min. Jour.*, 52, 403–404 (1931).

Spence, Hugh S.—Great Bear Lake Finds Look Good to Government Expert. *Northern Miner*, Toronto. 17 pp. 1 and 3 (Oct. 8, 1931).

Spence, Hugh S.—Radium and Silver at Great Bear Lake. Min. and Met., March, 1932.

"*Russia.*—It has been announced that the Moscow rare metals plant has succeeded in producing radium on a factory scale; no information is given on the size of the plant, the quantity of radium produced; or the source of the ore, presumably of domestic origin."

Emanation.

Radium decomposes at constant rate into the gas radium emanation (Radon), the amount of emanation in contact with the radium thus builds up until the rate of decay of the emanation exactly balances the rate of its formation. At this point the radium and its emanation are said to be in equilibrium with each other. The amount of emanation in equilibrium with one gram of radium, as measured by the intensity of the gamma rays emitted, is called a curie.

In medical practice, the emanation is pumped from the parent radium salt (usually in solution) and condensed from the gases with which it is mixed by cooling to liquid air temperature. Each gram of radium in the equilibrium state yields 0.6 mm.^{3} of gas per day. This condensed gas is pumped into a small glass bulb and the bulb sealed. Ordinarily the bulb is then enclosed in a brass capsule for protection against breakage. As freshly pumped off the emanation reaches its maximum intensity of gamma radiation within a few hours, the time necessary for the production of the maximum amount of radium C, which is the chief source of gamma rays. In medical practice it is customary to pump off the emanation each day. With this procedure one gram of radium will yield 160 millicuries of the emanation per day of which a skilled operator will recover about 150 m.c. Accumulating this emanation day by day will build up a permanent stock of emanation with an aggregate strength between 800 and 900 millicuries available for radiographic purposes.

Most of the radium in this country, and therefore most of the emanation also, is in the possession of the hospitals. It may sometimes be found possible to arrange with them for the use of bulbs of emanation during hours when they are not used for treatments.

Mesothorium.[29]

Before the cheaper radium from Africa was available, mesothorium was used in luminous paints. It was a by-product of the working of monazite sand to recover thorium for use in incandescent gas mantles. Monazite is essentially a complex phosphate of the rare-earth elements cerium, lanthanum and didymium associated with varying amounts of other compounds chiefly thorium oxide. Germany, Brazil, Ceylon, India, South Africa, and United States produce either thorium or monazite sand products.

GENERAL SUMMARY.

1. The first demonstration of the practicability of radiography of metal objects by gamma rays was made at the Naval Research Laboratory, Washington, D. C. in 1929.
2. The nature and properties of gamma rays are described, together with the sources and their rates of decay.
3. The scattering of gamma rays in radiography is more favorable both as to angular distribution and as to modification of wave-length than is that of X-rays. The absorption coefficient in iron under radiographic conditions is about .225 cm.^{-1}.
4. The rate of action on the photographic film of the rays may be intensified as much as 35 times (and the exposure times reduced proportionately) by the use of thick screens of calcium tungstate in contact with the film.
5. The exposure times necessary for steel and other metals are given in Figs. 18 and 19. *For single objects* the exposure times are shorter with X-rays for thicknesses of steel below 4 inches and shorter for gamma rays above this thickness.
6. The sensitivity of the method is such that flaws as

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[29] "Mineral Industry," McGraw-Hill Co., 1926, p. 472.

slight as 2 per cent. in a test object of total thickness of 4 inches can be revealed. The best conditions are (*a*) a concentrated source, (*b*) a long distance between source and film, and (*c*) the flaw as near as possible to the film. The sensitivity is, of course, less than that of the X-ray method.

7. In routine testing the entire space about the source should if possible, be occupied by objects thus reducing proportionally the cost per object tested. Safe procedure in handling the source is suggested.

8. The cost of radiography by gamma rays is computed for various conditions. If seven or more objects of steel one inch thick are exposed simultaneously, the cost of testing objects of this thickness is less than for testing single objects by X-rays. Above four inches thickness the cost is less with gamma rays even for single exposures.

9. The principal source of radium today is the Upper Katanga District of the Belgian Congo in Africa. Recent discovery of radioactive ore in Canada may prove important. Mesothorium, radium and emanation each possess certain advantages for radiographic use.

10. The principal advantages of the gamma ray method are: (*a*) the portability of the apparatus, (*b*) the simplicity of its operation, (*c*) the capacity to test very thick sections of metal, (*d*) the ability to test a great many objects at one time, (*e*) the low operation, maintenance and obsolescence costs.

The author wishes to acknowledge with gratitude the assistance of Dr. Robert F. Mehl and Dr. Charles S. Barrett of the Carnegie Institute of Technology, and that of Dr. Robert Canfield of the Naval Research Laboratory.

BIBLIOGRAPHY.

1. Mehl, Doan and Barrett: "Radiography by the use of Gamma Rays." *Trans. Amer. Soc. Steel Treating*, 18 September (1930), 1192.
2. Barrett, Gezelius and Mehl: "The Technique of Radiography by Gamma Rays." *Metals and Alloys*, 1 December 1930, 872.
3. Gilbert E. Doan: "Inspection of Welds with Gamma Rays." *Trans. A. S. S. T.*, September 1931.
4. R. F. Mehl: *Jour. Amer. Soc. Naval Engineers*, 43 (1931).
5. Gilbert E. Doan: Symposium on Welding, Amer. Soc. Testing Materials, Pittsburgh, March 1931.
6. C. W. Briggs and R. A. Gezelius: *Trans. Amer. Foundrymen's Asso.* (1931), 65.

7. R. Berthold and N. Riehl: "Grundlagen der Werkstoff prufung mit Gammastrahlen." *Z. d. Verein deutscher Ingenieure*, 76 (1932), p. 401.

8. "Der gegenwartige Stand der Roentgen durchstrahlung von Metallen." Siemens-Reiniger-Veifa, Berlin, 1928.

9. X-rays in Industry, Eastman Kodak Co., 1929.

9*a*. U. S. Bureau of Mines Info. Circular No. 6312, Aug. 1930.

9*b*. U. S. Bureau of Mines Report of Investigation No. 3057, Dec. 1930.

9*c*. U. S. Bureau of Mines, Mineral Resources No. 1: 7, Dec. 17, 1929, Part 1, pp. 135–140.

10. E. Rutherford: "Radioactive Substances and their Radiations." Cambridge, 1913.

10*a*. A. F. Kovarik and L. W. McKeehan: "Radioactivity." Bull. Nat. Res. Council, X, 51, 1925.

11. K. W. F. Kohlrausch: "Handbuch der Experimental physik," Vol. XV, 1928.

12. Meyer U. Schweidler: "Radioaktivität." Teubner, Berlin, 1927.

13. F. Soddy: "Chemistry of Radioactive Elements." Longmans, Green.

14. Z. Elektrochemie "Symposium Radioaktivitat," Mai 1932.

15. R. Berthold: "Grundlagen der technischen Roentgendurchstrahlung." Leipzig, 1930.

16. *Scientific American*, April 1931.

17. *Electrical Engineering*, p. 630, 1931.

18. *Literary Digest*, p. 27, May 30, 1931.

19. Lehigh Alumni Bulletin, Oct. 1931 (reproducing letter from Asst. Secretary of Navy, Jahnke).

20. *Science News Letter*, September 26, 1931.

21. *Iron and Coal Trades Review*, London, November 14, 1930.

22. *London Daily Mail*, Atlantic Edition, September 9, 1931, p. 10.

23. *Manufacturers Record*, Baltimore, Md., March 17, 1932.

Consumption of Dairy Products in Philadelphia.—F. F. LININGER AND HUTZEL METZGER (Pennsylvania State College, School of Agriculture and Exp. Sta., Bull. 245, 16 pages, 1930) have published data concerning the consumption of dairy products by 1,370 families resident in various parts of the city of Philadelphia, and representative of the different incomes, nationalities, and occupations. During the 5 year period, from 1924 to 1929, total milk consumption increased as the result of increases in both population and per capita consumption, the latter having attained a value of 0.68 pint daily in 1929, and having increased 11.6 per cent. during the period. The consumption of milk and of other dairy products (cream, condensed milk, skim milk, buttermilk, cheese, ice cream, butter, butter substitutes) was influenced by income, nationality, and size of family. However, the use of condensed or evaporated milk and of butter substitutes was relatively slight. Milk consumption was lowest among negro families.

J. S. H.

Decay of Stone—SYDNEY G. PAINE, FRANK V. LINGGOOD, FREDA SCHIMMER, AND THOMAS C. THRUPP (*Philos. Tr. Royal Soc.*, Series B, 1933, CCXXII, 97–127) report the occurrence of acid-forming bacteria, nitrifying bacteria, and sulphur-oxidizing or thionic acid bacteria in decaying building stones. The acid-forming bacteria produce acids from organic compounds; carbon dioxide is evolved when they grow upon the surface of sound stone. The nitrifying bacteria (*Nitrosomonas enropœa*) are chance infections derived from the soil, yet they can act upon sound stone to produce its partial solution. When acids derived from sulphur attack a stone, crystalline efflorescences, composed of calcium sulphate and sodium sulphate, appear on the stone. These sulphur-acids may be produced by sulphur-oxidizing bacteria, or may have their origin in the gaseous compounds of sulphur present in the atmosphere. When the sulphur-oxidizing bacteria grow on culture media, their colonies are embedded in masses of mucilage. The suggestion is made that, if this mucilage be present with the colonies in stone, it plays a part in the disintegration of the stone; for a tearing strain would exist as the mucilage alternately expanded and contracted as the result of imbibition and desiccation. The sulphur-oxidizing bacteria are widely distributed on decaying stones.

J. S. H.

THE SENSITIVITY OF THE FINGER-TIP TO VIBRATIONS AT VARIOUS FREQUENCY LEVELS.

BY

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Numerous attempts [1] have been made to determine the frequency limits of perceptible mechanical vibrations, and almost as many figures, ranging from 1300 to 2700 d.v., have been set by different experimenters as the upper limit. From a consideration of the physical fact that the energy required increases as the square of the frequency, we readily see that the amplitude of the vibrations must necessarily become exceedingly small as the higher frequencies are reached unless the activating power is greatly increased. Since this apparently has not been done, it would seem that the upper limits as set by the experimenters cited above are not true thresholds—being functions of the intensity of stimulation rather than the actual upper frequency thresholds or limits of sensitivity. This supposition is supported by experimental evidence from Dr. Gault's laboratory in which observers have been able to feel vibrations as high as 8192 d.v./sec. provided additional amplification were added for the higher frequencies. Consequently, we assume for the present that within limits, the apparent upper threshold is a function of the intensity of stimulation. Hence our problem is the measurement of the sensitivity of the finger-tip [2] to vibrations of different frequency levels.

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[1] For example, see the following: Gault, R. H., "Upper Limits of Vibration that can be Distinguished by Touch," *Science*, 1927, 65, 403–4. Kampie, A., "Experimentelle Untersuchungen über die praktische Leistungsfahigheit der Vibrationsempfinden," *Arch. f. d. ges. Psychol.*, 1930, 76, 3–70. Knudsen, V. O., "Hearing with the Sense of Touch," *J. Gen. Psychol.*, 1928, 1, 320–52.

[2] The finger-tip was chosen because it is used by the deaf and by most of our observers for teletactor experiments and it is the most convenient part to use.

The vibrations were communicated to the finger-tip by means of a revised form of the Gault Teletactor.[3] The receiver was placed in a soundproof box into which the observer thrust his arm through a hole made to fit. That this apparatus eliminates all possible auditory cues has been demonstrated in a previous investigation.[4] The activating current was supplied by a 2-A Western Electric audiometer and a 7-A amplifier to which additional stages were added for the upper frequencies.[5]

Twenty persons observed for us in this experiment, and eleven of them returned to the laboratory a month or so later to repeat the experiment, thus giving some check on reliability.

Intensity thresholds were determined for each of the twenty observers at each of the following frequencies: 64, 128, 256, 512, 1024, 2048, 4096 and 8192 d.v./sec. The attenuator dial of the audiometer was set so as to give a very intense vibration and was gradually decreased until the observer reported that he could no longer feel the vibration. After making six determinations in this manner, the same number of determinations was made by approaching the threshold from below, and the average of these twelve determinations was taken as the threshold. The gain in the amplifier was measured for each frequency level and found to be between 20 and 45 decibels. Since the audiometer is calibrated in decibels above the sensitivity of the normal ear, the average audiometer dial setting plus the amplifier gain for that particular frequency gives the sensitivity of touch in decibels below the sensitivity of the normal ear. These data for each observer are presented in Table I.

Twelve of the observers were tested again a month or so later and the changes are given in Table II. It will be observed that the average change is approximately six decibels,

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[3] This consists of two plates of Rochelle Salts Crystal (2½" × 2½" × 1/8") separated by a thin sheet of mica. The crystals are clamped at three corners and the fourth corner, which carries a small knob, is free to vibrate with the oscillations of the current. The observer places his finger-tip upon the knob in order to feel the vibrations.

[4] Gault, R. H. and Goodfellow, L. D., "Eliminating Hearing in Experiments on the Tactual Interpretation of Speech and Music," *J. Gen. Psychol.*, 1933.

[5] The author is indebted to A. W. Krause, E.E., of the Physics Department of Northwestern University for his help and suggestions in getting proper instrumentation for the experiment.

TABLE I.

The Sensitivity of Touch in Decibels Below the Sensitivity of the Normal Ear.

Observer.	Frequencies.							
	64	128	256	512	1024	2048	4096	8192
1	33	47	62	78	94			
2	39	53	64	84	102	117	117	119
3	46	56	75	94	108			
4	41	57	68	92	109	123	118	89
5	39	52	75	97	105	108	115	
*6	41	51	67	93	103	116	114	
*7	35	45	62	79	99	121	93	84
8	36	46	52	72	92		100	95
9	34	48	62	88	105	119	112	
10	32	42	47	78	87	105	89	
11	44	54	69	90	98	117	120	
12	49	57	79	97	107			
13	39	52	64	87	105			
14	36	44	62	93	110	113	75	
15	37	47	54	71	94	100	106	86
16	43	57	74	100	112	111	116	
17	52	62	74	97	106	123	105	92
18	40	63	81	100	105			
19	42	57	73	95	97	119	99	91
20	56	63	78	101	108	122		
Aver.	41	53	69	89	102	115	105	91
P.E.	1.2	1.4	2.0	2.2	1.6	1.9	3.5	1.9

* Deaf observer.

TABLE II.

Change in Sensitivity over Interval of a Month or More.

Observer.	Frequencies.						
	64	128	256	512	1074	2048	4096
2	19	5	11	12	10	9	
3	− 1	− 2	2	15	3		
4	3	0	− 3	1	3		
6	− 9	− 8	−13	− 7	− 5	−13	
7	−14	−11	9	− 6	−10	− 3	
8	− 2	− 9	0	0	0	0	
9	15	17	10	13	− 1	− 9	
11	5	4	5	3	−16		
13	8	13	5	6	4		
14	− 2	1	− 9	4	−11	3	
16	− 3	0	1	2	10	1	
20	0	5	− 3	0	3		
Aver.	6.7	6.2	5.9	5.7	6.3	5.0	

and since the unit step is five decibels, these changes may be considered relatively insignificant.

From the data in Table I it is possible to compute roughly the relative sensitivity of touch and hearing, which is done in the table III. For example, at 64 d.v/sec. a tone which can be just barely heard must be increased 41 decibels or 112 times to be perceptible to the finger-tip, while a tone five octaves higher (2048 d.v/sec.) must be increased 115 decibels or over half a million times to be detected by the sense of touch.

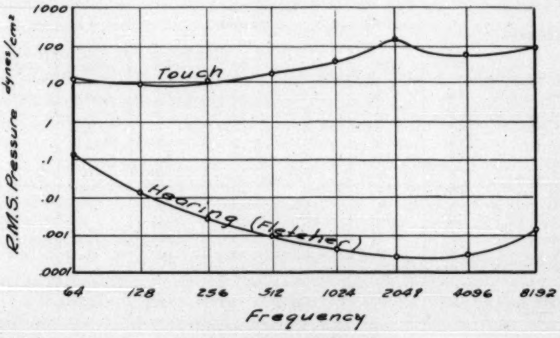
TABLE III.

The Superiority of the Ear over the Finger-Tip in the Perception of Vibrations.

Frequency.	Superiority of the Ear in Decibels.	Relative Sensitivity of Touch and Hearing.
64	41	112
128	53	448
256	69	2870
512	89	28,700
1024	102	127,000
2048	115	560,000
4096	105	178,000
8192	91	35,000

On the basis of these data showing the relative sensitivity of touch and hearing, it is possible to make an estimate of the sensitivity of the finger-tip on the basis of Fletcher's work on the sensitivity of the ear. This has been done in Fig. 1.

FIG. 1.



Sensitivity of the ear and finger-tip.

The amplitude of the vibrating diaphragm was measured by means of an optical system using a 100-foot beam of light as a lever arm. The following table gives the excursion of the diaphragm (without load) for the average intensity threshold at each frequency level.

TABLE IV.

The Amplitude of the Vibrating Diaphragm (without load) at the Average Intensity Threshold for Each Frequency.

Frequency.	Amplitude in Millimeters.	Power Input in Milliwatts.
64	.01074	
128	.00800	.01*
256	.00970	.04
512	.00990	.10
1024	.02200	.30
2048	.02208	1.44
4096	.02080	6.25
8192	.01070*	

* This figure is only an estimate.

It should be noted that the above values were obtained when the finger was not upon the vibrator. Consequently the true threshold values would be somewhat lower. Since the pressure which each observer exerted upon the vibrating knob is unknown, it is impossible to correct the above values for the damping effect of the finger.

Considering the ear as a highly developed and specialized touch organ, one sees in Table II on the relative sensitivity of touch and hearing, the extreme degree of sensitivity the ear has developed. Besides being of general theoretical interest, this study has a special bearing on the work of Dr. Robert H. Gault in the extension of the use of the sense of touch for the deaf. Since the differences in the sensitivity of touch and hearing vary with the frequency, it appears that an ideal amplifier for the Gault Teletactor[6] would be one whose gain was the reverse of the curve for the sensitivity of touch. With this sort of differential amplification, the deaf observer would perceive through touch all pitches in the same intensity relation as the normal person does through hearing. Consequently, it should increase greatly the effectiveness with which the deaf interpret speech felt over the teletactor. Such an amplifier is now being constructed.

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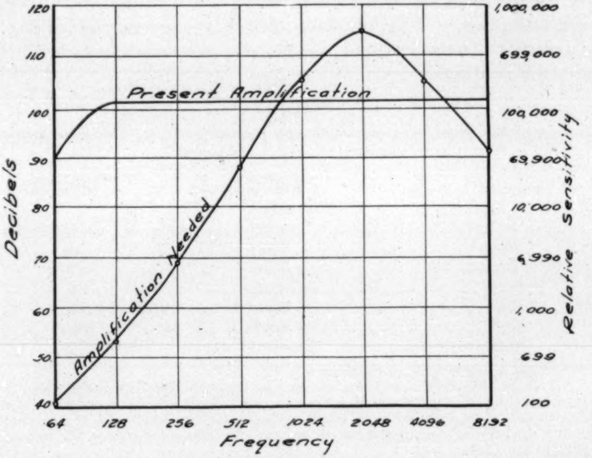
[6] The Teletactor is an apparatus developed by Prof. Gault by means of which the Deaf receive through their fingers, the vibrations of speech and music. As the Deaf learn to interpret these vibrations, the senses of touch and vibration may be said to be taking over the functions of the normal ear.

FIG. 2.



Amplification needed at each frequency level to compensate for differential sensitivity of touch, and the amplification being used at present. (0 decibels = normal auditory threshold.)

Fig. 2 shows the amplification needed and the amplification used in the past. From it one readily sees that the lower frequencies are greatly over-amplified and the higher frequencies are not sufficiently amplified to correct for the differential sensitivity of touch and hearing at different frequency levels.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

VARIATION IN THE ISOTOPIC COMPOSITION OF WATER FROM NATURAL SOURCES.

The discovery (*J. Chem. Phys.*, Vol. 1, p. 426; 1933) that water can be fractionated by distillation suggests that water in nature, which has undergone long continued evaporation, may have an isotopic composition different from that of circulating meteoric water. The specific gravity of pure water from each of the following natural sources was accordingly measured with the results shown. The values given represent specific gravity increases in parts per million, the specific gravity of normal water being taken as unity.

Dead Sea	2.1 ± 0.5
Great Salt Lake	2.7 ± 0.7
Rasorite (native borax tetrahydrate)	6.9 ± 0.3

This appears to be the first instance of a variation in isotopic composition in nature, in the case of non-radioactive elements.

ELECTRICAL CHARACTERISTICS OF RUBBER-SULPHUR COMPOUNDS.

The first American-made submarine telegraph cable was laid by the Signal Corps of the U. S. Army from Seattle, Washington, to Sitka, Alaska, about 1900. This was also the first long cable to be insulated with rubber instead of gutta-percha. The new venture, however, was far from satisfactory. When replacement was considered shortly after the World War, the Bureau was asked to determine whether rubber was, or could be made, suitable for the insulation of a submarine cable. A survey of the situation indicated that too little was known of the basic electrical properties of rubber to justify a forecast as to its suitability for that purpose. Accordingly, in order to avoid a possible failure involving an outlay of the order of a million dollars, gutta-percha insulated cable, though more expensive than a rubber insulated one, was obtained and laid in 1924.

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* Communicated by the Director.

In order to prevent recurrence of this situation at a future date a thorough and unhurried study of the electrical properties of rubber was begun by the Bureau in 1921, and has been continued up to the present time. Papers were published, one in 1925 and another in 1927, giving results of this investigation. The information obtained has already saved the Government much more than the cost of the investigation, to say nothing of the valuable data made available to industry.

Recently another chapter has been added to the record of this investigation in the form of a comprehensive report which will be published as Research Paper No. 585 in the August number of the *Bureau of Standards Journal of Research.*

The measurements reported in this paper were made on rubber which had been treated to remove impurities normally present in the natural gum rubber as it comes from the tree. Whereas the electrical properties of natural rubber depend on the source from which it is obtained, the properties of the purified rubber were found to be relatively constant and independent of the source.

This purified rubber was vulcanized with sulphur in a number of different proportions to form products which ranged in an unbroken series from gum rubber through the different variations of soft rubber, then through a group of materials of decreasing extensibility and increasing hardness, and ending in the various modifications of hard rubber. Accurate measurements of electrical properties were made on these products over wide ranges of conditions. The temperature was varied from − 75° C. (− 103° F.) at which even the softest rubber became hard and brittle, to 235° C. (455° F.), at which the rubber began to decompose rapidly on account of the heat. Frequencies were used from 60 cycles per second, which is employed for ordinary light and power purposes, to radio frequencies of 300,000 cycles per second. The results provide data which the electrical engineer can use in designing insulation whether for a power line, a radio instrument, or a submarine cable.

THE STANDARD-CELL COMPARATOR, A SPECIALIZED POTENTIOMETER.

From the pioneer days when the early telegraph engineer expressed a value of electromotive force as being so many

"Daniells" down to the present time, a galvanic cell of some sort has constituted the one material standard suitable for reproducing and maintaining the unit of electromotive force. The vast amount of research which has been expended on the Clark and the Weston standard cells has brought them to a high degree of perfection. The "Weston normal cell" is a standard of the highest importance in the maintenance of the volt by the national standardizing laboratories and in the intercomparison of their respective values of this unit. The portable form of the Weston cell is very widely used as a working standard of electromotive force, not only in the laboratory, but to a much greater extent as a necessary component of industrial recording and controlling devices operating on the principle of the potentiometer.

In recent years the exacting and refined absolute measurements, which are the necessary prelude to the revision of the values of the electrical units in international use, have called for augmented precision and accuracy in the intercomparison of standard cells. To meet this need, a special potentiometer has been developed at the Bureau. With it, two standard cells can be compared and a direct indication obtained of the electromotive force of one in terms of that of the other (the "reference cell") to one part in ten million. The calibration error of the instrument is only a few parts in ten million, and correction for it may be made if desired. In the design and construction of this potentiometer all available precautions and refinements have been utilized in order that it shall meet the exacting requirements of the new era in the history of the electrical units.

EFFECT OF GLASS CONTAINERS ON THE ELECTROMOTIVE FORCE OF WESTON NORMAL CELLS.

The Weston normal cell is the primary standard for electromotive force. It is, therefore, important that the electromotive force of such cells should be both reproducible and constant. Pure materials are required in order to construct cells that shall have the same electromotive force within a few microvolts, and many studies have been made of the stability of the ingredients. In the past, however, but little attention has been paid to the effects produced by the glass containers. It is well known that certain kinds of glass are appreciably soluble in water and in various solutions. In addition it is known that inequalities in the acidities of the electrolyte in various parts of the cell may result in large changes in electromotive force. A series of experiments has therefore been made at the Bureau to determine whether changes in the acidity of the electrolyte produced by the slight solubility of the glass walls of the cell would produce appreciable changes in electromotive force. The results will be published as Research Paper No. 588 in the August number of the *Bureau of Standards Journal of Research*. It has been found possible to accelerate the experiments by adding samples of glass in powdered form to the mercurous-sulphate paste. The effects of the powdered glass have been found to parallel the behavior of standard cells, prepared in the ordinary manner, over a much longer period of time. Various chemical compounds have also been added to the paste to test their effect on the electromotive force of the cells. The effect of the various added materials has been found to be surprisingly large and as a result of the investigation the glass containers have been redesigned with a view to improving the constancy and portability of the cells.

THERMAL EXPANSION OF COLUMBIUM.

Columbium is one of the rare metallic elements that is coming into prominence at the present time. Although it was discovered in 1801, it has become available in appreciable quantities only during the past few years.

In 1929, Balke published an article in which he described the preparation of columbium and indicated its applications. He states that there seems to be no question of the great value of tantalum and columbium in the construction of vacuum tubes. These metals may be of value because of their ability to absorb gases. He also states that columbium can be stamped or drawn with or across the grain without serious danger of splitting, and its ability to spotweld either to itself or to other metals, when soft-annealed and free from gas is quite unusual.

At the Bureau measurements have been made on the linear thermal expansion of a rod of columbium containing 0.93 per cent. tin and 0.26 per cent. iron. Data were obtained at various temperatures between − 135° and 305° C. (− 211° and 581° F.). The following equation was derived by the method of least squares:

$$L_t = L_0 \left[1 + (7.06\, t + 0.00144\, t^2)\, 10^{-6}\right].$$

In this equation L_0 represents the length of a specimen of columbium at 0° C. and L_t the length at any temperature t between − 135° and + 305° C.

The coefficient of expansion increases regularly with temperature. From 0° to 100° C. the average coefficient of expansion is 7.2×10^{-6} per degree C., approximately 35 per cent. less than the coefficient of expansion of ordinary steel. This metal therefore seems likely to be useful in apparatus or appliances where moderate expansion is required.

Research Paper No. 590 in the August number of the *Bureau of Standards Journal of Research* will give more details of this work, including a table of the coefficients of expansion of columbium over various temperature ranges.

OPTICAL AND OTHER PROPERTIES OF THE NORMAL FORMATES OF SOME GROUP II METALS.

The Bureau will publish as Research Paper No. 587 in the August number of the *Bureau of Standards Journal of Research*, values for the refractive indices, optic axial angle, elongation, dispersion, and interference figures for the normal crystalline formates of calcium, strontium, barium, magnesium, zinc, and cadmium. The crystal system and habit are likewise given. The presentation of data of this type for series of organic compounds makes the polarizing microscope available as a means of identifying these compounds, with added convenience and economy of time as a result.

The densities, and the solubilities in water from 0° to 100° C., frequently useful in the separation or identification of compounds, are also given for these formates. The solubilities all increase with increasing temperature. The formates of calcium and barium in equilibrium with the saturated solution are anhydrous over the entire range; those of magnesium and zinc are the dihydrated salts. Strontium formate shows a transition from the dihydrate to the anhydrous salt at 72° C., and cadmium formate shows a similar transition at 66° C.

The system magnesium formate-water was investigated, and a eutectic mixture was found containing 14.0 g. of magnesium formate (calculated as anhydrous salt) per 100 g. of of water at − 5.05° C.

The accuracy of the various determinations is evaluated, and is discussed in connection with previously published work on these compounds.

A relationship of the molal concentrations of the salts in saturated solutions at various temperatures, an adaptation of Dühring's relation, is also discussed.

ALKALINITY OF LIME SOLUTIONS.

The chemical utilization of lime has developed to such an extent that about half of the country's production of lime now goes into manufacturing industries. Many chemical processes involve the use of aqueous solutions of calcium hydroxide and are concerned with reactions wherein saponification, hydrolysis, causticization, coagulation, and neutralization play an important part. The control of such reactions often requires information on the alkalinity of the lime solutions. An investigation was, therefore, undertaken at the Bureau to secure fundamental data relative to the strength of calcium hydroxide as a base.

Measurements of the pH of calcium hydroxide solutions at 30° C. over the concentration range 0.050–1.199 grams CaO per liter were made using the hydrogen electrode in conjunction with the saturated calomel half-cell, correcting for the potentials of the liquid junction occurring in this cell. The data permit calculation of the activity coefficients of hydroxyl ion in solutions of calcium hydroxide. As the activity coefficients are a measure of the thermodynamic degree of dissociation of the electrolyte, the values of the hydroxyl ion obtained, lying between 0.86 and 0.94 over the concentration range studied, indicate that calcium hydroxide is a relatively strong base. The maximum alkalinity of its solutions is limited, however, by its relatively low solubility. In a saturated calcium hydroxide solution the activity coefficient of the calcium ion was computed to be 0.49. The value 1.72×10^{-14}

at 30° for K_w, the dissociation constant of water, was derived from the data. A more complete account of this work will be published as Research Paper No. 584 in the August number of the *Bureau of Standards Journal of Research.*

IGNITION OF PALLADIUM COMPOUNDS.

Methods for the determination of palladium (in chemical analysis) usually require igniting some compound of palladium to the metal. When this is done in air the metallic residue always has a blue or purple color, instead of the gray color of palladium sponge, indicating that the metal is partially oxidized. Some methods direct that the residue be heated in an atmosphere of hydrogen to reduce the oxide, others that the residue be treated with a few drops of formic acid and dried, for the same purpose. The latter method is not always effective and the former is open to the objection that the palladium sponge absorbs a considerable quantity of hydrogen which may be catalytically oxidized to water when the sponge is exposed to the air.

It has recently been found that the foregoing difficulties can be avoided by cooling the sponge, after ignition in air, in an atmosphere of carbon dioxide, rather than hydrogen. The oxide or oxides of palladium which may form during the ignition of compounds of the metal in air are completely dissociated at temperatures readily attainable in porcelain crucibles heated with ordinary laboratory burners. If the metal is finally heated briefly in an atmosphere of carbon dioxide and allowed to cool in this gas no oxide is formed and the residue can be weighed directly, as metal.

Recent work has also confirmed that palladium can be very accurately determined by precipitating it with dimethylglyoxime, followed either by drying and weighing the compound (factor 0.3167) or by very carefully igniting it, under the conditions described above.

REVISED COMMERCIAL STANDARD FOR FUEL OILS.

Commercial Standard CS12–33 on Fuel Oils (Second Edition), which was released by the Bureau last month, covers the important characteristics essential to satisfactory burning oils. Six distinct grades are described with limits as to flash point, water and sediment, pour point, distillation range and viscosity. Experience has indicated the necessity of limiting the above characteristics in order to provide for the satisfactory burning of fuel oils which before the appearance of definite grade standards was limited only by gravity—an index now looked upon as a very poor indicator of volatility or viscosity.

In addition to the above requirements there are some oils used for heat treatment and in glass and ceramic furnaces, and other special uses where a low sulphur requirement is necessary. To meet this special need the second edition of this standard carries a table showing sulphur content of each grade that may be used by the purchaser of these oils.

The standard was originally published in 1929 as the Commercial Standard for Domestic and Industrial Fuel Oils CS12–29 but upon recommendation of the standing committee it was revised and with some minor changes was recommended for acceptance under the abbreviated title of "Fuel Oils," CS12–33.

Endorsement of the revised standard was received from practically all the more important oil refiners, many distributors and organized consumers, together with practically all the burner manufacturers. Accordingly the revised standard was made effective May 1, 1933.

The pamphlet, in addition to the standard specification, includes a list of acceptors and a brief history of the project. Copies can be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents each.

LETTER CIRCULARS.

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THE FRANKLIN INSTITUTE.

LIBRARY NOTES.

RECENT ADDITIONS.

American Institute of Chemical Engineers. Transactions, 1932, Volume 28. 1933.

American Institute of Mining and Metallurgical Engineers (Iron and Steel Division). Iron and Steel Technology in 1928.

Appleyard, Rollo. Charles Parsons, his Life and Work. 1933.

Beringer, Bernard. Underground Practice in Mining. 1928.

Boulton, W. H. The Pageant of Transport through the Ages. No date.

Bragg, Sir William. The Universe of Light. 1933.

Chatley, Herbert. Studies in Molecular Force. 1928.

Clay, Reginald S., and Thomas H. Court. The History of the Microscope, Compiled from Original Instruments and Documents, up to the Introduction of the Achromatic Microscope. 1932.

Drysdale, C. V., and Others. The Mechanical Properties of Fluids. 1925.

Euklid. Die Elemente. Nach Heibergs Text aus dem Griechischen übersetzt und herausgegeben von Clemens Thaer. Ostwald's Klassiker der exakten Wissenschaften. Nr. 235, 236. 1933.

Gregory, J. W. The Story of the Road from the Beginning Down to A.D. 1931. 1931.

Hardenbergh, W. A. Home Sewage Disposal. 1924.

International Astronomical Union. Transactions. Volumes 1–4. 1922–1933.

Jahrbuch für Photographie, Kinematographie und Reproduktionsverfahren für die Jahre 1928–1929. Herausgegeben von Josef Maria Eder. Einunddreissigster Band, II Teil. 1933.

Jellinek, Karl. Lehrbuch der physikalischen Chemie, Erste und zweite Auflage, dritter und vierter Band. 1930–1933.

Kaempffert, Waldemar. A Popular History of American Invention. Volumes 1–2. 1924.

Laurens, Henry. The Physiological Effects of Radiant Energy. American Chemical Society Monograph Series. No. 62. 1933.

Lowrie, Sarah D., and Mabel Stewart Ludlum. The Sesqui-Centennial High Street. 1926.

Mantell, C. L. Sparks from the Electrode. 1933.

Nord, F. F., and R. Weidenhagen. Ergebnisse der Enzymforschung. Band 2. 1933.

Ower, E. The Measurement of Airflow. Second edition. 1933.

Read, William Thornton. Industrial Chemistry. 1933.

Richards, Edward S. Chromium Plating: a Text-Book for the Practical Electro-Plater, the Productive Engineer and the Student. 1932.

VOWLES, HUGH P., AND MARGARET W. The Quest for Power from Prehistoric Times to the Present Day. 1931.

ZAHN, BERT. Silk Screen Methods of Reproduction for Sign Painters, Card Writers, Display Men, Furniture Decorators, Novelty Manufacturers, Glass Etchers and for Domestic Use. 1930.

BOOK REVIEWS.

APPLIED COLLOID CHEMISTRY, by Wilder D. Bancroft. Third Edition, 544 pages, 24 figures, 64 tables, 14 × 21 cms. New York, McGraw Hill Co., 1932. Price $4.00.

Here is an old friend and yet a new one for this entertaining volume has been rewritten, not merely touched up with a dab of new information here and there. Professor Bancroft is an extremely rapid reader with a tremendous memory. As a result his books and articles include and correlate facts which most of us would never find. Moreover, they are presented with a seasoning of wit which holds the interest and recalls the amusing but keen discussions of papers at meetings Professor Bancroft attends. We find, for example, "It was Edward Lear who wrote about the Jumblies who went to sea in a sieve. He considered that a nonsense rhyme; but modern science is almost equal to the problem, for we can carry water in a sieve." Elsewhere we are told that "A. P. Mathews (1921) chided the colloid chemists for sailing under the black flag of adsorption" and "According to Aitken (1923) there are four billion particles of smoke formed per puff—brand of cigarette not stated."

However, it must not be thought the only or principal reason for reading this book is to pick out tid-bits such as these. It is a liberal education in colloid chemistry, as may be indicated by the list of chapter headings: adsorption of gas or vapor by solid, chemical reactions, adsorption of vapor by liquid and of liquid and solid by solid and liquid, adsorption from solution, surface tension—Brownian movements, coalescence, preparation of colloidal solutions, properties of colloidal solutions, electrical properties of colloidal solutions, stability of colloidal solutions, gelatinous precipitates and jellies, emulsions and foams, non-aqueous colloidal solutions, fog, smoke, gases and solids in solids, and thickness of surface films. The excellent index makes the material readily available.

In the first edition of this book colloid chemistry was defined as "the chemistry of bubbles, drops, grains, filaments, and films." This has been widely quoted, but the definition "Colloid chemistry is the chemistry of every-day life," gives the reason why almost all chemists and many others will find this book of interest. The author's belief that it "is probably best for those who are interested in colloid chemistry as chemistry rather than as mathematical physics" is reassuring for those who are reading for general information.

WM. STERICKER.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 456, The Aerodynamic Forces and Moments Exerted on a Spinning Model of the "NY-1" Airplane as Measured by the Spinning Balance, by M. J. Bamber and C. H. Zimmerman, 15 pages, illustrations, 23 × 29 cms. Washington, Superintendent of Documents, 1933. Price five cents.

A preliminary investigation of the effects of changes in the elevator and rudder settings and of small changes in attitude upon the aerodynamic forces and moments exerted upon a spinning airplane was undertaken with the spinning balance in the 5-foot vertical tunnel of the National Advisory Committee for Aeronautics. The tests were made on a 1/12-scale model of the "NY–1" airplane.

Data by which to fix the attitude, the radius of spin, and the rotational and air velocities were taken from recorded spins of the full-scale airplane. Two spinning conditions were investigated. All six components of the aerodynamic reaction were measured and are presented in coefficient form referred to airplane axes.

The results show that, except for pitching and yawing moments, the changes in forces and moments introduced by elevator and rudder movements were small and of the same order of magnitude as those introduced by small changes in attitude. The pitching moment was approximately doubled by movement of the elevator from 33° up to 27° down but was little affected by rudder movement regardless of the elevator position. A large yawing moment opposing the spin was introduced when the rudder was moved from full with the spin to full against the spin with the elevator up. When the elevator was down the yawing moment given by full rudder movement was reduced to approximately one-fourth its former value.

The results indicate that the change in yawing moment produced by the rudder with the elevator up was the only component of force or moment produced by the elevator and rudder that could not have been balanced in an actual spin by small changes in attitude and angular velocity.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS.

Report No. 457, Maneuverability Investigation of an "03U–1" Observation Airplane, by F. L. Thompson and H. W. Kirschbaum, 14 pages, illustrations, 23 × 29 cms. Washington, Superintendent of Documents, 1933. Price five cents.

This report presents the results obtained in maneuverability tests conducted by the National Advisory Committee for Aeronautics with an "03U–1" observation airplane. This investigation is the third in a series of similar investigations requested by the Bureau of Aeronautics, Navy Department, for the purpose of comparing the maneuverability of different airplane types and to provide quantitative data for use in establishing a criterion or method for rating the maneuverability of any airplane. The two former investigations were conducted with the fighter types designated "F6C–3" and "F6C–4" and have been reported previously.

Measurements of the air speed, the angular velocity, the linear acceleration, and the positions of the controls were made during abrupt single-control maneuvers with three stop positions for each control, during steady horizontal turns for the determination of minimum radius, and during 180° turns by various methods. Flight-path coördinates in two dimensions were determined for the 180° turns by means of a special camera obscura designed for the previous investigation of the "F6C–4" airplane. All maneuvers were performed at an altitude of approximately 3,000 feet.

The results of the abrupt single-control maneuvers are presented by curves showing the variation of the measured quantities with respect to air speed and control movement. The results of the 180° turns are shown by time histories of the measured quantities for one maneuver of each type and by a table giving principal flight-path dimensions, altitude change, speed change, time required for completion, and maximum values of recorded quantities for all turns. The minimum radius of turn for steady horizontal flight at an altitude of 3,000 feet was found to be 322 feet at 74 miles per hour as compared with 155 feet at 76 miles per hour and 135 feet at 62 miles per hour for the "F6C–3" and "F6C–4" airplanes, respectively.

AN OUTLINE OF ATOMIC PHYSICS, by the members of the Physics Staff of the University of Pittsburgh: Oswald H. Blackwood, Elmer Hutchisson, Thomas H. Osgood, Arthur E. Ruark, Wilfred N. St. Peter, George A. Scott, Archie G. Worthing. 348 pages, tables, illustrations, 15 × 23.5 cms. New York, John Wiley & Sons, Inc., 1933. Price $3.50.

There is no doubt but what this book fills in a gap that has existed for some time in the bulwark of physical knowledge being constantly buttressed by works limited more or less to some particular phase of the general subject. It furnishes a pleasant interlude among the more technical and specialized volumes. Do not be misled, "An Outline of Atomic Physics" has not been written for mere popular consumption. The authors are faculty members of the department of physics in a well-known university and the text represents the subject of their various lectures to advanced students, few of whom had dedicated their lives to this branch of science.

The authors announce their intention to steer a middle course. The various chapters have not been inflated with expansive algebraic terms nor historical derivations of the ultimate equations representing the well-established physical relationships. Rather, the conclusions have been approached through a process of logical reasoning and the intelligent but unspecialized reader finds himself at ease without experiencing a familiarity that eventually provokes contempt.

Instead of enumerating the chapters and their contents in the order presented, it is believed sufficient to assure all prospective readers that this book is as up-to-date as any scientific work can be and those new discoveries, of which many of us have received only a hint or smattering of information, are described comprehensively and evaluated as to their relative importance. To make our reference more specific we would mention the study of positive ions with the mass spectrograph, the wave-like behavior of charged particles, the Compton effect, Schrodinger's probability wave functions, atomic magnetic moments, cosmic rays, disintegration of elements, the neutron, relativity; stellar magnitudes, masses, densities, eclipsing binaries and star formation theories.

The final chapter, "New Light on Old Problems," has a philosophical tang. In it reference is made to the recognized limitations of mechanical atom models. A discussion of the "uncertainty principle" also occupies an appropriate place. Rather than ending up with "To be continued," as any book on physics might well do, this implied phrase is appropriately substituted by a final section on "Realms Unexplored." The authors conclude that "the quest is just beginning."

T. K. CLEVELAND.

PUBLICATIONS RECEIVED.

The World of Fossils, by Carroll Lane Fenton, 182 pages, illustrations, 13 × 19.5 cms. New York, D. Appleton-Century Company, Inc., 1933. Price $2.00.

Télévision et Transmission des images, par René Mesny, 216 pages, illustrations, 11.3 × 17.3 cms. Paris, Librairie Armand Colin, 1933. Price 10 f. 50.

Grundlagen der Photochemie, von Dr. K. F. Bonhoeffer und Dr. P. Harteck, 295 pages, tables, illustrations, 15 × 22.5 cms. Dresden und Leipzig, Theodor Steinkopff, 1933. Price 25 RM.

Untersuchungen über die Schlagwettersicherheit von Wettersprengstoffen unter betriebsmässigen Bedingungen, von Bergassessor Dr. Ing. E.h. Beyling und Bergassessor Schultze-Rhonhof, 125 pages, plates, 16.5 × 24 cms. Gelsenkirchen, Carl Bertenburg, 1933.

The Indian Forest Records, Interim Report on Work under Project No. 2, Strength Tests of Timbers in Structural Sizes, with Test Results up to 1932, by L. N. Seaman, 39 pages, tables, 18.5 × 24.5 cms. Delhi, Manager of Publications, 1933.

A Yearbook of Railroad Information, 1933 Edition, 96 pages, charts, 10 × 15.5 cms. New York, Committee on Public Relations of the Eastern Railroads.

Ontario Department of Mines, Forty-First Annual Report, The Pleistocene of the Toronto Region (Including the Toronto Interglacial Formation), by A. P. Coleman, 69 pages, tables, illustrations, maps, 16.5 × 25 cms. Toronto, King's Printer, 1933.

National Advisory Committee for Aeronautics, Technical Notes, No. 464, A Complete Tank Test of a Model of a Flying-Boat Hull—N. A. C. A. Model No. 11, by James M. Shoemaker and John B. Parkinson, 17 pages, tables, illustrations, 20 × 26 cms. Washington, Committee, 1933. No. 465, Some Characteristics of Sprays Obtained from Pintle-Type Injection Nozzles, by E. T. Marsh and C. D. Waldron, 6 pages, illustrations, 20 × 26 cms. Washington, Committee, 1933. No. 466, Engine Performance with a Hydrogenated Safety Fuel, by Oscar W. Schey and Alfred W. Schey and Alfred W. Young, 8 pages, illustrations, 20 × 26 cms. Washington, Committee, 1933.

CURRENT TOPICS.

An Anti-Soil-Erosion Device.—(U. S. Dept. of Agric. Clip Sheet No. 780.) In looking around for new and useful inventions, consideration might well be given to a machine which successfully prevents soil erosion and conserves moisture in soils. This machine is heralded by the issuance of a public service patent to Raymond H. Davis, soil erosion specialist of the U. S. Department of Agriculture. The device combines an ordinary cultivator with a set of shovels which dig about 10,000 holes an acre, giving a wafflelike appearance to fields. Actual field tests have proved the machine capable of completely controlling erosion when used on slopes up to 20 per cent. and has done much good on even steeper lands having highly erosive soil. The machine makes it possible to retain approximately 2 inches of rainfall without damage to the land from soil washing and with much benefit to crops, especially in regions of light rainfall, through increased storage of moisture. Use of the Davis soil-saving cultivator has materially increased yields of wheat and now it is being further tested on row crops such as cotton and corn.

C.

A Vinylite Dwelling.—(J. G. Davidson and H. B. McClure, *Ind. & Eng. Chem.*, **25**, 645.) The progress or development of a civilization or science may be divided into a series of Ages. It can truthfully be said that practical chemistry is now passing through the "Plastic Age." It's true, the plastics are chiefly synthetic and their inventors may be credited with showing nature a trick or two. Vinyl resins belong to the "thermoplastic" group as distinguished from the "thermosetting." The latter type of resin undergoes a reaction when heated and is rendered infusible while resins exemplified by the vinyl members may be rendered soft and plastic repeatedly, merely by heating.

The utility of the vinyl resins may be gauged readily enough upon learning they are odorless, tasteless, chemically inert and usually non-inflammable. Produced as either white and opaque or transparent and colorless granular powders they may be compounded with many types of fillers and dyes or pigments to give molded compounds of every variety of color and shade. The vinyl resins may be obtained in the form of compressed tablets, extruded tubes and rods, or thin sheets produced by hot calendering rolls.

The molding process is quite simple the time required being that of heating up the mold and cooling again. Resin to which a filler has been added is generally molded at pressures between 250 and 2,000 lb. per sq. in. and temperatures of 120° to 150° C. while the unfilled resins require pressures of 1,200 to 1,800 lb. per sq. in. and temperatures of 115° to 130° C.

The permanent thermoplasticity of the vinyl resins offers definite economies in the molding process. Practically all the scrap or "flash" may be reused. Another valuable property of these resins is their resistance to shrinkage and warpage. This has made possible the construction of molded panels 2 in. × 2.5 ft. × 8 ft. and weighing about 150 lb. each. Several years of effort have evolved a type of pure vinyl resin that is eminently satisfactory for dentures. The odor- and tastelessness of the resins also establish their suitability as food and drink containers. Remarkable decorative effects may be had by incorporating small amounts of aluminum bronze or "fish essence." Although the insolubility of the resins in alcohol, gasoline and ethers may prove an advantage in many instances these solvents are thereby precluded in the preparation of lacquers. Special types of ketones make the best solvents. A noteworthy property of these lacquers is their resistance toward alkalies which characteristic should make them quite suitable for coating composition materials having inherent alkaline reactions.

Success in the first attempts to produce doors and wall panels of molded vinyl resins led to an investigation on just how extensively these products might be used in the construction of an apartment dwelling. The apartment consisted of three rooms the walls were built of large eight-foot panels, while the doors, molded in the same general way, measured 6.5 ft. × 2.5 ft. × 0.5 in. The tiles were made by a technic similar to that used in producing asphalt tile and consisted of 22.5 per cent. resin, 2.5 per cent. plasticizer and 75 per cent. slate flour and pigment. Such tiles are easily kept clean and are not indented by the legs of chairs and other articles of furniture. All the illumination was transmitted by sheets of the resin, one-sixteenth inch thick. About 90 per cent. of the light passes through. Even the window panes consisted of translucent sheets of vinyl resin—the exterior vista did not warrant making the sheets transparent.

The molding around the ceiling, the baseboard and even the door sills was all made of the extruded resin. The various towel racks and grab bars in the bathroom were sections of the same material of proper design and cross sections. Vinylite was also used to mold the toilet seat, tooth brushes, cosmetic and powder jars, the closures on the tooth paste and shaving cream tubes as well as the cups, saucers, pitchers, tumblers, and trays in the kitchen cupboards. The same applies to all door knobs and electric light switches, even the ornaments, cigarette boxes, ash trays and lamp shades.

One firm has already designed machinery for the production of vinylite doors. They not only will be better than the usual wooden door from the standpoint of appearance, warpage and lightness, but will be much cheaper when installed because they are finished completely, even to the hinges, when they leave the factory. No labor will be necessary to hang them, except to fit the door knobs and lock into the place provided. There will be no necessity to plane or saw to make them fit since they will be molded to the size of any specified opening and of course will not have to be painted or varnished. The same observation applies to the floor tile, the wall panels and the cupboard doors.

C.

Activity of Enzymes at Low Temperatures.—The enzyme, *thrombase* or *thrombin* coagulates the plasma or liquid portion of the blood by acting upon the soluble protein, fibrinogen, and converting it into the insoluble, coagulated protein, fibrin, which forms the clot. In the course of an elaborate research on thrombase, JOHN MELLANBY (*Proc. Royal Soc.*, Ser. B, 1933, CXIII, 93–106) has studied the influence of temperature on the action of this enzyme. While a decrease in temperature diminished the rate of coagulation of plasma by thrombase, nevertheless, even at a temperature of 0° C., coagulation occurred rapidly in the presence of a large amount of thrombase. At this low temperature, the law of inverse proportionality still held true; *i.e.*, with a constant mass of plasma, the coagulation time increased as the mass of thrombase decreased. Mellanby suggests that a serum globulin is also formed in the enzymic coagulation of fibrinogen.

Saccharase, sucrase, invertin or *invertase* is the enzyme which hydrolyzes sucrose or cane sugar, producing invert sugar, which is an equimolecular mixture of *d*-glucose (dextrose) and *d*-fructose (levulose). Z. I. KERTESZ (*Zeit. physiol. Chemie*, 1933, CCXVI, 229–232) has studied this reaction, using yeast saccharase, at temperatures between 36.8° and −6.8° C., and finds that the velocity of the reaction decreases only slowly with decreasing temperature in the region below 0° C. M. A. JOSLYN (*Ind. Eng. Chem.*, Ind. Ed., 1933, XXV, 825) has also studied the influence of low temperatures on the action of invertase on sucrose, at a temperature of −18° C. His results "show definitely that enzymatic action can occur even in the hard frozen state."

J. S. H.

Whaling Industry.—LEWIS RADCLIFFE (*Ind. and Eng. Chem.*, Ind. Ed., 1933, XXV, 764–767) gives a concise history of the whaling industry and describes its present status. At present, the chief whaling region is the Antartic. Norway controls 60 per cent., England 30 per cent. of the total world production. In 1931, 42,874 whales were caught, and 184,349,000 gallons of whale oil were produced. In modern whaling, the factory ship is accompanied by whale catchers, which are fast motor boats or small steamers of 150 to 180 tons; it may be accompanied by oil carriers. The factory ship may render the oil from 15 or more whales, and produce 15,000 gallons of oil in a single day. Two grades of oil are obtained from the blubber by boiling it with water. A third grade of oil is produced by pressure cooking of the residue from the open digestors. Still another, somewhat inferior, oil results from pressure cooking of the flesh and bones. Whale oil represents approximately 5 per cent. of the total world supply of fats and oils. The domestic production in the United States is between 7 and 12 million pounds annually; in 1930 the importation of whale oil was 55,000,000 pounds for consumption and 75,000,000 pounds for storage in bond. The chief use in the United States today is for soap manufacture. After hydrogenation, the oil may be used not only for this purpose, but also as a constituent of oleomargarine and lard substitute. The American shore factories on the Pacific coast also produce guano and bone meal from whales. The better grades of whale meat are suitable for human consumption. The League of Nations is endeavoring to control whaling operations so as to conserve the supply and prevent its exhaustion by extermination of the whales.

J. S. H.

Factors Influencing the Vitamin Content of Foods.—R. ADAMS DUTCHER (Pennsylvania State College, School of Agr. Exp. Sta., Bull. 275, 24 pages, 1932) has compiled an excellent review of this important subject, including the factors which influence the natural or normal vitamin content of fresh foods of both plant origin and animal origin, and the influence of food treatment on vitamin potency. Under the latter heading, attention is paid to:—Harvesting and field factors, storage, heat treatment, desiccation and fermentation, pasteurization and evaporation, cooking and canning, and irradiation. The vitamins A, B, C, D, E, and G are considered. A bibliography of 86 references completes the work.

J. S. H.

Appetite and Choice of Diet.—LESLIE J. HARRIS, JANET CLAY, FLORENCE J. HARGREAVES, AND ALFRED WARD (*Proc. Royal Soc.*, Ser. B, 1933, CXIII, 161–190) have made numerous feeding experiments on rats suffering from vitamin B starvation to ascertain their ability to discriminate between rations containing that vitamin and those lacking it. The results demonstrate that the ability to discriminate does not depend upon a vague instinct, but is due to an association between distinctive properties of the ration (its effects upon the organs of smell, taste, and sight) and the beneficial effects on appetite, tone of the digestive tract, etc., which promptly follow its ingestion. An example may be cited. If a rat, suffering from lack of vitamin B, be permitted to eat his choice of a sufficiently large number of rations, he may be unable to select the particular ration containing the vitamin. Now, if he be fed only that particular ration during an education period of several days, he profits from his experience, and selects the proper, particular ration when again permitted to choose from the large group of rations. He may also be re-educated during another education period, if the source of vitamin be a vitamin concentrate, and it be transferred from a ration flavored with bovril to one flavored with cocoa. When the benefit is less readily experienced, the rat cannot distinguish between the deficient and the adequate diets. The authors believe that experience has played a prominent part in the determination of dietary preferences in general.

J. S. H.

Glass Autoclave.—GEORG KLEIN (*Ind. Eng. Chem.*, News Ed., 1933, XI, 187) describes an autoclave of 750 cc. capacity constructed of Jena glass with metal ends and capable of use at a temperature of 170° C., and a pressure of 7 atmospheres. It may be heated internally by electric heaters, or externally by use of a transparent heating fluid contained in a copper jacket which is provided with glass windows.

J. S. H.

Tellurium as an Insecticide.—In a recent current topic attention was called to the use of a solution of selenium in potassium ammonium sulphide $(KNH_4S)_5Se$ as an insecticide for the control of red spider. GNADINGER (*Ind. Eng. Chem.*, Ind. Ed., 1933, XXV, 634) has tested similar compounds of tellurium, but they were not as toxic, as stable, or as easily prepared as those of selenium.

J. S. H.

Alumina Cream.—I. R. LUPU (*Chemist-Analyst*, 1933, XXII, No. 3, 15) prepares alumina cream by boiling an approximately 1 per cent. solution of aluminium acetate in an open pail for 8 to 12 hours, replacing the water as evaporation occurs. The precipitated aluminium hydroxide is collected by filtration through canvas bags.

J. S. H.

Indium Sulphate.—RALPH P. SEWARD (*Jour. Am. Chem. Soc.*, 1933, LV, 2740–2744) has crystallized indium sulphate at room temperature from solutions free from excess acid, and obtained a compound with the formula $In_2(SO_4)_3 \cdot 9H_2O$. An acid salt, $In_2(SO_4)_3 \cdot H_2SO_4 \cdot 7H_2O$, was obtained in the presence of excess sulphuric acid, and a basic salt, $In_2O(SO_4)_2 \cdot 6H_2O$, precipitated on the addition of alcohol. Measurements of the hydrogen ion concentration demonstrated that a considerable degree of hydrolysis occurs in solutions of this salt.

J. S. H.

Fatal Poisoning by Sodium Nitrite.—H. B. ARBUCKLE AND O. J. THIES, JR. (*Ind. Eng. Chem.*, News Ed., 1933, XI, 202) describe a case of fatal poisoning following ingestion of sodium nitrite. This is the first case reported in the United States, although 6 cases have been reported abroad. A child, aged 2 years, ate sodium nitrite and died in approximately 15 minutes. The amount ingested is unknown. The chief symptoms were emesis and muscular weakness. After death, the gastric contents were alkaline and contained a considerable amount of sodium nitrite; the solid particles were a distinct chocolate brown color.

J. S. H.

Colloidal Paris Green as a Larvicide for Mosquitoes.—H. G. GRANT, BARCLAY M. NEWMAN, AND PIERCE D. WOOD (*Public Health Rep.*, 1932, XLVII, 1239–1247) report that colloidal Paris green, in concentrations as small as 1 part by weight in 5,000,000 parts of water, is toxic to the larvæ of the mosquito, *Culex apicalis*, under laboratory conditions. One such colloid killed all the larvæ, which were exposed to its action, within a period of 19 hours to 3 days.

J. S. H.

Sucrose Normal Weight.—An error of 0.1° exists in the 100° point of Ventzke scale saccharimeters. C. A. BROWNE AND R. T. BALCH (*Ind. Eng. Chem.*, Analytical Ed., 1933, V, 283) report the adoption, by the International Commission for Uniform Methods of Sugar Analysis, of a recommendation to permit for such instruments a normal weight (for sucrose) of 26.026 grams in 100 milliliters. The error of the scale is thereby corrected.

J. S. H.

Joseph Priestley.—In connection with the celebration of the bicentenary of the birth of Joseph Priestley, which occurred in 1733, DOUGLAS MCKIE (*Science Progress*, 1933, XXVIII, 17–35) has written a concise account of Priestley, the Chemist. As a research worker, Priestley discovered seven gases: oxygen, ammonia, hydrogen chloride, nitric oxide, nitrous oxide, nitrogen peroxide, and sulphur dioxide. He preserved an open mind in the controversy between the adherents and the opponents of the doctrine of phlogiston, and wrote: "the more satisfied I am at present with the doctrine of phlogiston, the more honourable shall I think it to give it up upon conviction of its fallacy." At one time, he tended to agree with Lavoisier; yet his last work, published at Northumberland, Pa., in 1803, was the second edition of his "Doctrine of Phlogiston Established."

J. S. H.

Thallium Poisoning.—JAMES C. MUNCH, HYMAN M. GINSBURG, AND C. E. NIXON (*Jour. Am. Med. Asso.*, 1933, C, 1315–1319) describe an outbreak of thallotoxicosis or thallium poisoning in California in 1932. "Thalgrain," or barley to which 1 per cent. of thallium sulphate has been added, is used in the control of the ground squirrel infestation. A 100 pound bag of thalgrain was stolen from a locked official warehouse; it was labelled "Thallium Poison Barley," yet was ground to flour and used in the preparation of tortillas, although it appeared abnormal, and behaved in an abnormal fashion during baking. At least 31 persons ate the thalgrain, an unknown amount being consumed by each; 20 of these persons developed symptoms of thallium poisoning within 1 to 3 days; 14 were hospitalized; 6 died of primary thallotoxicosis within 16 days; the others survived under treatment, although 1 died about 2 months later. Thallium was present in detectable amounts in the kidneys, liver, lungs and spleen obtained at autopsy of the fatal cases. The chief symptoms were loss of hair and marked disturbances of the gastro-intestinal and nervous systems. The treatment includes gastric lavage, use of cathartics other than sulphates, fixation of the thallium as its iodide by intravenous administration of sodium iodide, elimination gradually by natural means aided, if desired, by administration of small doses of sodium thiosulphate, use of calcium salts if calcium metabolism be disturbed, and general treatment of such symptoms as develop. If thiosulphate mobilize the fixed thallium too rapidly, recourse must again be had to fixation by iodide.

J. S. H.

A Different Complexion.—(*Science Service.*) The day *Science Service* published a report on "argyria," a strange disease, some of the newspapers told the story of a West Indian negro who had turned white as the result of accepting treatment from his tribal "medicine man." This patient, had constantly suffered from asthma and the prescriptions of regular physicians had done him no good. As a last resort, the sick man placed himself in the hands of the medicine man who gave him pills made from the seeds of a certain plant growing in that locality. As a preliminary, the patient went blind and his hair fell out. Gradually his sight returned and the black pigment of the skin completely disappeared. Incidentally, the asthma was cured. Practically nothing is known about the active principles contained in the seeds except that an organic cyanide, a derivative of prussic acid, is present.

Although instances such as the above are extremely rare, cases where white people turn a greyish-blue color promise to be more plentiful. According to *Science Service* this phenomenon is called "argyria" and results from taking medicines containing silver salts over a long period of time. In the final stages this greyish-blue color is quite pronounced and if the victim is exposed to sunlight, his skin turns a very dark mahogany brown. These silver salt medicines are often given in the treatment of nose and throat ailments and in many cases their application is continued by the patient long after the physician has ceased to prescribe them.

The blue discoloration makes its first appearance around the base of the nails and gives timely warning that the treatment must be discontinued. The blue color is produced by the precipitation of silver albuminate in the tissues and once the color is established, there is no satisfactory remedy for the condition. Although the health is not impaired, the disease is disturbingly disfiguring.

C.

Laminated Resin and R-B-M.—Not so very long ago the Mellon Institute of Industrial Research described a new material of construction bearing the name "Robertson Bonded-Metal." So far as we know this product consists of a metal sheet, probably of steel, to the surfaces of which non-metal materials such as fabrics or sheets of vegetable fiber are bonded by means of metal alloys having relatively low fusion points. Attention now is called to the growing popularity of laminated articles formed from sheets of resin-impregnated fabric or paper. These sheets are piled upon each other to give the desired thickness, then the pile is subjected to heat and pressure, so welding it into one solid piece.

The Institute points out the eminent suitability of the bonded-metal sheets as a component of these laminated resin objects. The metal serves to give rigidity to the panel while the attached fabric or porous fiber board aids in forming a very solid bond between the metal and the resin. Veneered steel panels presenting very attractive surface effects also may be obtained by selecting colored and printed fibrous layers for the R-B-M, saturating with resin varnish, drying and pressing to cure the resin and to secure the desired finish.

C.

The Centenary of Gaston Plante.—The French Society of Electrical Engineers have begun preparations for celebrating the hundredth anniversary of the birth of Gaston Plante, a great French scientist and inventor of the storage battery. Plante's invention made available quantities of electrical energy at relatively high voltage and amperage and came at that period where high voltages and low currents were obtained from electrostatic machines and high currents but only low voltages were practicable with the galvanic piles.

One of the simpler stunts performed by Plante with his accumulators was to charge them singly or a few together by means of the galvanic piles. Then by connecting these charged batteries in series he secured a tension of 600 volts at quite high amperages. Another scheme was to charge a battery of condensers in parallel by means of his accumulators. By connecting these charged condensers in series, a discharge of over 100,000 volts was obtained. Few are they who do not realize or appreciate the importance of storage batteries in the present-day development of electrical apparatus and machinery. The development of Plante's invention has been far reaching, the applications are legion, the inventor has justly merited the honor and homage that are to be paid him by his grateful countrymen and appreciative scientists of other countries.

C.

The Scopometer.—A company, wellknown for the manufacture of optical instruments, has recently announced a new device for measuring the turbidity of liquids, the Exton Junior Scopometer. Although the instrument ranks high in accuracy, its chief importance probably lies in the ease and rapidity with which all turbidimetric determinations can be made. The criterion used is the matching of an illuminated line against a field of constant intensity. The match is brought about by adding to the density of the sample to be measured a second density derived from a variable neutral wedge. This wedge travels in vertical ways and is held in any position by springs. Two scales are mounted on either side of the neutral wedge. One is graduated in millimeters while the other is left blank and is meant to be marked with any direct-reading scale the technician may desire. The color filters are held in a rotating sector and may easily be swung in or out of the field. Another attractive feature is that the measurements are made using the test tube in which the reaction is originally carried out.

C.

Finical Plants.—(U. S. Dept. of Agric. Clip Sheet No. 784.) Most of us assume that almost any plant will grow in a soil, poor though it is, if it has been treated with some standard fertilizer containing potash, phosphate and nitrogen in some form. Of course, a certain amount of moisture always is necessary. However, we are told that all kinds of winter vegetables now thrive on areas in southeastern Florida where a few years ago nothing would grow without heavy applications of compost. An investigation by the Department's soil scientists disclosed a deficiency of manganese in the soil. When a little of this element was added in some convenient form normal crops appeared. Another case of manganese deficiency was discovered farther north in a bean and pepper district along the east coast of Florida. Where soybeans failed to grow normally in eastern North Carolina small quantities of manganese solved the problem.

Other experiments have shown that small quantities of other of the less common elements are essential to crops. It was found that minute quantities of copper on Everglades peat lands overcame their previous failure to respond to fertilizers. Farmers regularly apply copper sulfate to the peat soil and unproductive lands south of Lake Okeechobee now produce good crops of sugar cane. Mere traces of copper have benefited citrus trees in Florida, truck crops in North Carolina and tomatoes and sunflowers in Minnesota.

C.

An Unique Camp Stove.—(U. S. Dept. of Agric. Clip Sheet No. 786.) The United States Forest Service describes how a small but efficient camp stove can be made by filling a large coffee can half full of sand or earth and pouring in a cupful of gasoline. Punch 3 or 4 holes in the can just above the level of the sand. A cupful of gasoline will burn 40 to 50 minutes, enough to heat water or soup. A help in starting a camp fire in wet weather is to use a tablespoonful or two of sawdust dampened with kerosene.

C.

Homogenization of Milk and Cream. F. J. DOAN AND C. H. MINSTER (Penna. State Col., School of Agric. and Exp. Sta., Bull. 287, 20 pages, 1933) report that the efficiency of homogenization increases as the angle between the valve seat and the wall of the chamber increases, and as the distance between the valve and the wall decreases. Unless the milk or cream be heated to a temperature of 150° F. or higher prior to homogenization, its hydrogen ion concentration increases after homogenization, and rancidity also develops, frequently in a few hours. Changes in surface tension depend upon the temperature of preheating. The changes in both hydrogen ion concentration and surface tension are attributed to the liberation of soluble acids by hydrolysis of the fat by lipolytic enzymes. Clumping of fat in the product is governed by the temperature of preheating and that of homogenization, and is greatly reduced or entirely eliminated by two-stage homogenization.

J. S. H.

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